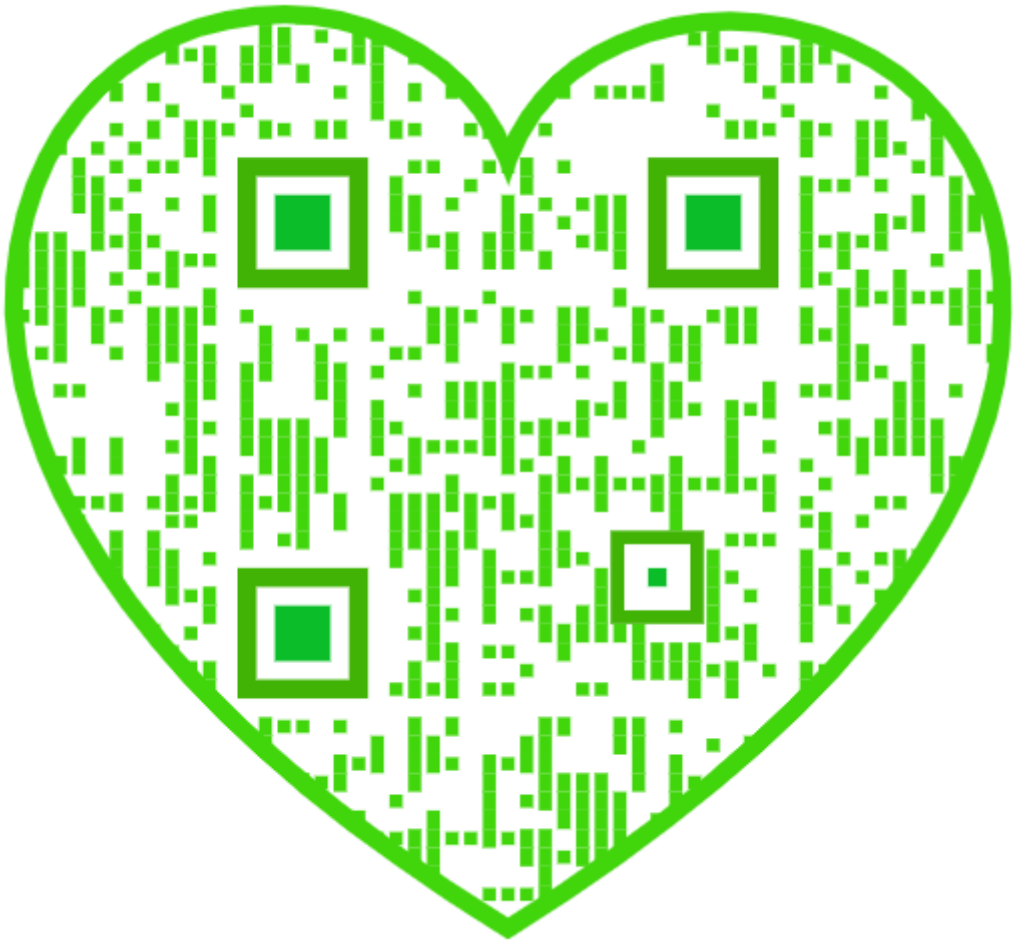

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PHYSICAL EFFECTS

OF

COMPRESSED AIR,

AND OF THE

CAUSES OF PATHOLOGICAL SYMPTOMS

PRODUCED ON MAN, BY INCREASED ATMOSPHERIC PRESSURE

EMPLOYED FOR THE SINKING OF PIERS,

IN THE CONSTRUCTION OF THE

ILLINOIS AND ST. LOUIS BRIDGE

OVER THE

MISSISSIPPI RIVER AT ST. LOUIS, MISSOURI,

BY

A. JAMINET, M. D.

ST. LOUIS, MO.

R. & T. A. ENNIS, STATIONERS AND PRINTERS, 118 OLIVE STREET.

1871.

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PREFACE.

Having no pretensions as a writer, I ask the indulgence of my readers in offering this result of my thoughts and observations, which I have divided into twelve chapters, as will be seen hereafter.

The first eleven chapters of this pamphlet were prepared for publication on the fifteenth of August, 1870. By unforeseen circumstances, however, its appearance was delayed, but the delay in its publication has not caused me to alter anything advanced therein. The facts observed during the sinking of the caisson for the East abutment pier, and which are contained in Chapter XII, on the contrary, have confirmed me in my conclusions, as to the truth of the cause or causes of the physiological and pathological phenomena observed on the men working in an over-condensed atmosphere.

A. JAMINET, M. D.

St. Louis, Mo., 15th August, 1871.

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CHAPTER I.—Preliminaries.

In any great undertaking, and in engineering and architectural structures, especially on a large scale, there are difficulties which are only met with as the work is progressing; even the projector himself cannot devise means to overcome those difficulties but when he meets them.

In the prosecution of a vast engineering, undertaking, stupendous, even in its conception, as is the construction of a bridge over the Mississippi river, at St. Louis, Mo., to connect the Illinois shore with the State of Missouri, great difficulties had to be overcome, and among them the one of which we will speak hereafter.

To Mr. J. B. Eads, of this city, was reserved the honor to be the foremost who conceived and dared to undertake such an immense work—work replete with difficulties to overcome, to project and mature all the plans, devices and appliances necessary for the execution, accomplishment and success of such an unprecedented undertaking.

The first thing to be done, and which was a severe test on his engineering skill, was to devise the mechanical means to sink the piers in the river until the rock shall be reached, so as to insure permanent and solid foundations for the immense spans which are to rest on the piers, the bridge being an arched bridge, (not a suspension one,) but composed of three spans or arches, constructed entirely of steel.

It was found necessary by the projector, to build four piers to support the three spans of five hundred and twelve feet each; one pier on the western shore, and three piers in the Mississippi river; said piers to be built on caissons made of very thick

iron, with *an air-chamber underneath*, being nine feet high inside, and of the same area of the piers, which for the west pier in the river is 2,600 feet, for the east pier 3,600 feet, and for the east abutment pier 4,800 feet. Each caisson divided into three compartments by longitudinal timber partitions to support the deck or ceiling of the caissons, and at the same time the masonry work, which was to be built *over the air-chambers* during the progress of the sinking of the caissons.

The caissons reaching the bed of the river, the water to be excluded completely *from the air-chambers under each pier*, by means of air-pumps forcing compressed air *into the air-chambers*, to enable men to work at the excavating and removal of the sand, eighty feet deep, *to reach the rock at the place where the piers had to be sunk;* the excavating of the sand and its removal from the bed of the river to be made by means of sand-pumps until the caissons and piers built over them will *rest upon the rock.*

The working men in order to reach the air-chamber or interior of the caissons under the piers had to go down by circular stairs in a shaft, in the centre of the piers, the stairs leading to the bottom of which were the *air-lock or intermedtate chamber* and the *air-chambers*, are situated.

The air-lock is a cylinder, made of very thick iron, six feet in diameter and six feet high, and having two doors large enough to admit easily the passage of a man; one door on the north side of the shaft to go from the shaft into the air-lock, and another door on the east side of the air-lock to go from the *air-lock* into the *air-chambers*. The first door closing inside the *air-lock* when the compressed air is admitted by opening a valve to equalize the pressure in the air-lock with the *air-chambers*, and to allow the door between the *air-lock* and the *air-chambers* to open when the pressure is equalized in both.

The door between the *air-lock* and the *air-chambers* closing inside the air-chambers, so that the compressed air, forced by the air-pumps into the air-chambers, keep the door perfectly closed, while the compressed air is left to escape by another valve in the air-lock, and which the men have to open, after closing the door from the air-chambers to the air-lock, when leaving their work, and return to the normal atmosphere.

From the project to the subsequent commencement of the work, and its successful continuance without interruption, we know the result. The work progressed so far that the east pier, with its caisson, was sunk, and the rock was reached on the 28th of February, 1870.

To perform such a work at the depth of ninety-five feet below the surface of the river — which depth increased in the east pier to one hundred and ten feet five inches on April 12th, by the rise of water, and this, without any interruption of the work—was more than was anticipated.

Once the rock reached and the caissons with the piers built over them and resting on the rock, and all the sand in the air-chambers or caissons removed, the filling of the caissons with concrete had to be done to let the piers rest on the rock on solid masonry, to insure permanent solidity and success of the work.

Of the sinking of the two first piers, and filling up of the air-chambers with concrete, the result surpassed all expectations of its projector. It was only when, arrived at the bed of the river, and under the water, which had to be *excluded entirely from the air-chambers or caissons* by the compressed air forced by the air-pumps, that the air had to increase in density to equalise by its pressure the outside pressure caused by the water in the river.

The atmospheric pressure had, consequently, to increase also in the *air-chambers or caissons* as the work of excavation, removal of sand, and sinking of the piers progressed, and when the caisson at the east pier touched the bed of the river, the pressure was seventeen pounds to the square inch *exclusive of the fifteen pounds of our ambient atmosphere.*

The pressure increased gradually, and rose on the 28th February, 1870, when the east caisson touched the rock, to forty-five pounds to the square inch, and by the rise of the water in the river, during the months of March and April, increased still more, so that on April 12th the pressure was fifty (50) pounds to the square inch. The air being compressed to such an extent, and men being obliged to work in it, it was supposed that it might become injurious if their remaining in the air-chambers was too prolonged. In consequence, the men at work were directed to remain in the *air-chambers* only two hours at a time, with two hours rest between each two hours work, three times a day, making six hours in all for a day's work.

The sinking of the caissons and the building of the piers over them progressed, but, notwithstanding all the precautions taken, the pressure *increasing every day in the air-chambers*, and having reached twenty-four pounds to the square inch, the caisson being then fifteen feet in the sand at the east pier, and fifty feet under the surface of the river where the men were working, then, some of those at the east pier, *after coming out of the air-chambers*, and when in *the air-lock*, or *after leaving the air-lock*, and returning into the normal atmosphere, commenced to suffer and complain of very severe pains in the arms and legs, and sometimes of shooting pains in the back. *None were affected when in the air chambers or caisson, but always after returning into the air-lock, or going out of the air-lock and returning to the normal atmosphere.*

The sinking of the piers becoming deeper, the pressure also increased, and when it had reached thirty-four pounds to the square inch, the men became more seriously affected; some of them with violent epigastric pains, and others with paresis, and some with slight paraplegia, of which they generally recovered in from twenty-four to forty-eight hours. Sometimes the paraplegia was more severe, and some were taken with still more serious symptoms, as paraplegia, involving the bladder and rectum. Notwithstanding the existing paralysis, some of those affected complained of violent pains about the middle of the spine, and radiating in every direction of the lower half of the body.

As soon as cases happened means were devised at the bridge to relieve the sufferers if possible, even temporarily, and afterwards they were sent to the City Hospital. (The first case sent to the Hospital was on the 15th February, 1870.) Some died shortly after their arrival at the Hospital, and some after a sojourn there. Inquests were held by the Coroner of the County on the bodies of those who died.

After the recurrence of such facts and accidents, physicians were called at the bridge to see the men at work, and when taken sick, which was generally the case *when coming out of the air-lock, or after returning into the normal atmosphere. None, and we repeat it from official authority, were taken sick in the air-chambers*, and the sufferers were generally taken, in from a few minutes to one hour after they returned into the normal atmosphere, and in two cases only *did it occur in the air-lock as soon as the door opened into the normal atmosphere, and not in the air-chambers or caisson.*

At the inquests held by the Coroner, and after the *post mortem* examinations on the bodies of the men who died at the City Hospital, the opinions about such cases, given by two medical gentlemen of this city, were

sustained, and their descriptions of the pathological changes given, were published in newspapers and medical journals.

We admit the correctness of their pathological observations on the patients, which they have called bridge cases, as also their description of the pathological changes observed during the *post mortem* examinations, but we differ on the cause or causes which produce or have produced those pathological symptoms, as also the pathological changes, and even death of the patients, which have come under their observation, and we will relate our own experience, and the observations made by us in the caissons, at the bridge, and on the men engaged at work in the air-chambers.

Having been for over six years Mr. J. B. Eads' physician, and meeting him frequently, we had the opportunity of becoming initiated in the furtherance of his great project to build *an arched bridge across the Mississippi river at St. Louis*; and with the means and devices of engineering which he intended to employ for prosecuting the work, and sinking of the piers, we became so interested in the matter, that from the time the project became a reality by the commencement of the work, we thought that questions of great importance to scientific men would be met with, and that the use of compressed air to exclude entirely the water from the air-chambers or caissons, *sunk at the depth of one hundred and fifteen feet, and perhaps more*, below the surface of the river, (*work never performed before at such a depth, the deepest ever before reached being sixty-five feet;*) that the air used at such a depth would have to be condensed to a pressure as high, may be, as fifty-five pounds to the square inch, and would certainly require close observations in its use as it might produce on the men therein engaged pathological phenomenas, with more or less serious effects on health and life.

Hence, from the first day of the sinking of the caisson for the east pier, in November, 1869, we commenced observations and experiments, which we will have under consideration, the perusal of which may, at first, seem uninteresting, but the reader will find them necessary to a full understanding of the subject we have undertaken.

CHAPTER II.

PHYLOSOPHICAL OBSERVATIONS ON THE INFLUENCE OF COMPRESSED AIR AND ITS PHYSIOLOGICAL EFFECTS ON MAN.

The ambient atmosphere in which we live, is of all things to man, the most necessary to life and to the preservation of health; and if, by circumstances dependent or independent of his will, the respirable air in which he has to live, even for a short time, is undergoing some changes in its normal condition, his organism may be effected by it, his health impaired, even severely compromised, and in some cases death may be the result, *if his remaining in certain abnormal atmosphere has been too prolonged.*

The air may vary in its constituents according to temperature and barometrical changes, having more water at one time than at another, but is always in such normal condition as to sustain life, that man can live in it and be in good health, but if the condition of the atmosphere is changed, not in proportion of its constituents, *but in its density, as in a compressed atmosphere to a high pressure, as it is in the air-chambers* at the bridge, the men to live *in such abnormal atmosphere*, to work and to sustain life, may stand it well for a certain length of time, but this very limited, and only by taking the necessary precautions *to avoid a too sudden transition* from the normal atmosphere to an over-condensed one in which they are temporarily at work, and then return again, all at once, into the normal atmosphere where human beings can live in good health.

In the normal atmosphere, which surrounds us, the pressure is fifteen pounds to the square inch on every

part of our body, but still we do not feel this pressure when we move or during severe muscular exertions, as in hard work. *Consequently, for the sake of convenience and clearness on the subject we have under consideration*, we will count only the atmospheric pressure resulting from the height of water *above the air-chambers or caissons under the piers*, exclusive of the fifteen pounds of our ambient atmosphere.

The first time we were in the caissons, the pressure was only five (5) pounds to the square inch. We were not affected in any way; we remained in them twenty minutes, and afterwards we went twice a week, when the pressure was increasing about one pound per day. Still we did not feel any inconvenience, and it was only when the caissons had touched the bed of the river, the pressure having increased to sixteen pounds to the square inch, that for the first time, in going through the air-lock, we felt a pressure upon both tympanis—pressure of which we relieved ourselves by swallowing some of the air to produce contrepressure; our breathing was 20 per minute and free; our pulse, from 81 per minute when normal, rose to 89. Three minutes after we were in the *air-lock or intermediate chamber*, we felt a pain in the frontal region which lasted about two minutes; we were six minutes going through the air-lock, that is to say, passing from the normal atmosphere to a pressure of sixteen pounds to the square inch, existing *in the caisson or air-chambers.* Once in the air-chambers we felt as well as in the normal atmosphere. After fifteen minutes sojourn in the caisson, our pulse fell again to 81 per minute, being the same as in the normal atmosphere. We remained half an hour longer in the caisson, going round examining the works, and before returning into the air-lock, our pulse was only 75 per minute, but from which we felt no inconvenience.

When in the *air-lock in order to return to the normal atmosphere*, our stay was only four minutes, our pulse

remained the same, 75 per minute only. We felt cold after being two minutes in the air-lock, the temperature decreasing rapidly, the cause being the too rapid escape of the compressed air through a valve which was open for the purpose of equalizing the pressure with the normal atmosphere in the shaft, and to allow the door to open to return into the open air.

We successively visited the air-chambers every four or five days without any inconvenience, and until the caisson had sunk to sixty-nine feet below the surface of the river, and the atmospheric pressure had increased to thirty-two and one half pounds to the square inch. On the two last visits we were longer in going through the air-lock and felt more inconvenience from the frontal pain. Our pulse rose to 100 per minute during *our stay in the air-lock*; our breathing remained free, but was 21 per minute and continued the same while remaining in the air-chambers.

We remained *in the air-chambers thirty minutes*, after which time our pulse was only 72 per minute; and during *our sojourn in the air-lock*, to return to the normal atmosphere, we felt the same inconvenience of cold, by the too rapid escape of the compressed air, the temperature decreasing still more rapidly; we remained only six minutes in the air-lock on our return to the normal atmosphere, and after opening the door leading to the shaft and in ascending the stairs *we had to rest two or three times, being exhausted and breathing heavily.* From that day we were perfectly satisfied that the men having to work every day in such an ambient atmosphere, and with the prospect of increasing pressure, might at any time suffer and even become affected with very serious symptoms. Then we continued our visits at the piers and at the

EAST PIER, FEBRUARY 10TH, 1870—11 o'clock, A. M.

Barometer 29° 45′, the thermometer 53°; weather clear. The caisson being sixty-nine feet under the surface of

the river, the pressure being thirty-two and one half pounds to the square inch in the air-chambers, we commenced to make systematic and regular observations, as follows:

(For our observations and experiments we used thermometers of Farenheit, made by Greener, from Berlin.)

There were six of us to go down in the caisson or air-chambers: I, forty-six years old, and the other five averaging twenty-nine years.

Our pulse were respectively, 81—78—78—79—79—80 per minute, regular and healthy. The measures of our chest were, after inspiration, 40 inches—37½—37—37½—37—35¾, and after expiration, 38—36—35—35½—35—34. The complexion and general appearance of each was healthy.

After descending the circular stairs, which lead to the air-lock at the bottom of the shaft, the thermometer was 56°. There were in the air-lock at the time we reached the bottom of the shaft, eight persons just coming out of the air-chambers. *We entered the air-lock, being seven persons, six of us and the lock-tender. The door was closed, the valve from the air-chambers opened to let the compressed air enter the air-lock and equalize the pressure as in the air-chambers or caisson. We were ten (10) minutes in the air-lock to equalize the pressure with the air-chambers.* Four of our number felt no inconvenience except complaining of a pain of their tympanis, of which they relieved themselves by swallowing some of the air, the lock-tender at the same time *relenting the ingress of the compressed air in the air-lock.* The thermometer was 56° when we entered the air-lock and rose in seven minutes to 62°.

Our pulse before entering the air-lock were respectively 81—78—78—70—79—80 per minute, and six minutes after rose to 100—88—98—86—95—90 per minute.

As the equalization of pressure took place in the air-lock as in the air-chambers, and by opening the door

from the air-lock to the air-chambers we entered them, the pressure being at the time thirty-two and one half pounds to the square inch, and the thermometer indicating 48°. After remaining twenty minutes in the air-chambers, we felt a marked exhilaration through all our system. We remained two hours in the air-chambers, during which time we made observations, as follows:

After two hours sojourn in the caisson, our pulse from 81—78—78—79—79—80 when normal, fell to 68—70—71—69—70—72 per minute.

In the measure of our chests there was no change for inspiration or expiration with the normal atmosphere.

It will be observed that during the time we remained in the caisson we used no muscular exertions by any forced labor. We observed, also, during our sojourn, that all of us, and the men working in the air-chamber, were covered with profuse perspiration, and this with the thermometer at only 48° Farenheit.

During the time we were in the caisson, we made experiments and observations to ascertain the temperature of ebulition of different liquids at such a pressure. The temperature of ebulition of water, sulphuric ether and alcohol under atmospheric pressure had been ascertained before, *but by experiments made in the laboratory only*, and until this day it was not supposed possible that experiments and observations on the influence of pressure on the temperature of ebulition could be made under the pressure of three or four atmospheres, or forty-five pounds pressure to the square inch, exclusive of the fifteen pounds of our ambient atmosphere, and the observer to be exposed to such pressure himself during his observations.

We therefore claim priority for the following observations made in such an ambient atmosphere.

We had a platform made supported by four columns three feet high, and insulated in their continuity with

the soil by glass rods resting on the sand at the bottom of the air-chambers. The platform upon which the experiments were to be made was insulated, and if there was *a current or an accumulation of electricity in the air-chambers*, the result of the experiments would be influenced as little as possible by it.

We heated one pint and a half of distilled water in a red copper capsule offering thirty-seven square inches of heating surface to a large alcohol lamp fitted with three cotton wicks and containing six ounces of alcohol. During the experiments two thermometers graduated to five hundred degrees Farenheit, made by Greener of Berlin, were used so as to compare the accuracy of each and ascertain if there was any difference in the result. Both thermometers marked 270° Farenheit during the ebulition of distilled water. We repeated the same experiment three times with the same result.

We experimented afterwards with a glass capsule of the same capacity as the red copper one, and found that the thermometer rose to 274° before ebulition.

We do not present this fact as a new one. *The difference of temperature of ebulition in different kinds of vessels, was observed before by* Gay Lussac, a French chemist, but in the normal atmosphere, where the temperature rose from 212° Farenheit to 216½°: but we were desirous to compare if the difference was proportionately the same, between a metalic vessel and a glass one, under a pressure of thirty-two and one half pounds to the square inch, besides the fifteen pounds of the normal atmosphere.

We repeated the same experiments with filtered Mississippi river water, the thermometer indicating 268° during ebulition in a red copper vessel and 272° in a glass one.

We noticed an interesting fact, but which we will leave our readers to solve, and which was repeated

three times in successoin. It was that when the distilled water was in ebulition in the red copper vessel, and the thermometer indicating 270°, if we touched the platform with our hand, the platform ceasing to be insulated, by ourselves being in communication with the soil, the thermometer fell three degrees in the course of a few seconds and ebulition ceased temporarily, and recommenced when the thermometer rose to 270°, but only after the platform became reinsulated from the soil by the withdrawal of our hand from the platform.

After our experiments, and having remained two hours in the caisson, the thermometer from 48° when we entered rose to 50°. We then returned into the air-lock, and after closing the door from the air-chamber, the compressed air was left to escape in the shaft by the escape valve, and thus equalize the pressure to open the door to return into the normal atmosphere.

After *leaving the air-chambers and during our stay in the air-lock*, we felt cold as in our subsequent visits, even more so. The temperature decreased very rapidly by the too rapid escape of the compressed air, and after four minutes sojourn in the air-lock, the thermometer, from 50° at our entrance, fell to 37°. We were only five minutes and a half returning to the normal atmosphere at the bottom of tbe shaft, where, on examining the thermometer, we found the temperature to be 50°, and before ascending the stairs our pulse was 69—70—69—71—68—72 per minute.

In returning to the normal atmosphere we had to ascend the stairs, as we have said before; *in ascending them some of us had to rest two or three times, breathing heavily*, and after returning to the surface of the pier our pulse was 106—104—92—94—102—99, and rather feeble, the appearance of five of us was pallid and sallow, one had no notable change. This concluded the first regular observation.

In order to avoid useless repetitions we will epitomise the results of subsequent observations.

EAST PIER, FEBRUARY 12th, 1870—11 o'clock, A. M.

Barometer 29° 80′. Thermometer 28°. Weather clear and cold. Caisson seventy-one feet below the surface of the water. Pressure thirty-three and one half pounds to the square inch.

We were four persons only. I, forty-six years old, one thirty-four, one twenty-nine, and one thirty-two. Before descending the stairs our pulse was resectively 81—81—74—74 per minute. The measure of our chests were, after inspiration, 40—38—38 and 39 inches. After expiration it was 38—36—35½ and 36 inches. Our general appearance and complexion healthy.

When we arrived at the bottom of the shaft, the temperature was 46°. We entered the air-lock, four persons beside the lock-tender, who was *directed to let the compressed air in very gradually, so as to stay eleven* (11) *minutes in the air.lock before the pressure should be equalized with the air-chambers.* On entering the air-lock the temperature was 47°, but increased to 62° *during our stay there.* Before entering the air-chambers our pulse was 98—97—84—88 per minute; our breathing free but 21 respirations per minute. None of us felt any pain in their tympanis, neither any other inconvenience during the equalization of pressure with the air-chambers in which the temperature was 46° when we entered them. After being twenty minutes in the air-chambers we felt that same exhilaration all through our system observed before.

Then we repeated the experiments on the temperature of ebulition on distilled water, Mississippi water, Alcohol, sulphuric ether and chloroform, with the following results.

For the distilled water the thermometer marked 271° in a red copper vessel and 274½° in a glass one.

For Mississippi river filtered water the thermometer marked 269° in a red copper vessel and 272½° in a glass one.

The experiment of laying the hand on the platform, to suspend its insulation was repeated; the thermometer, at each time insulation ceased, successively fell three degrees, after a few seconds ebulition ceasing also, but commenced again as soon as the thermometer rose to the figure before observed, and by the reinsulation of the platform by withdrawing the hand from it.

We proceeded afterwards to experiment on alcohol, sulphuric ether and chloroform, for which a water bath was used, and with the following results:

Alcohol in ebulition, 224°. (Alcohol fortius.)

Sulphuric ether in ebulition, 122°. (Ether fortior.)

Chloroform in ebulition, 179°. (Chloroform purificatum.)

The experiments with alcohol, sulphuric ether and chloroform were repeated three times with the same results.

After our experiments were over, and having remained two hours in the caisson, the temperature was 50°. Our pulse from 81—81—78—78 when in the normal atmosphere fell to 66—68—66—69 after our sojourn in the air-chambers. The measure of our chests were unchanged. It was observed that during the time we were in the air-chambers, we, as also all the working men, *were perspiring profusely.* During our sojourn in the air-chambers our speech seemed changed, but after repeated observations of this phenomena we explained it. According to the laws of acoustics, the air being compressed at the pressure of thirty-three pounds to the square inch above the normal atmosphere, the undulations of sound or waves cannot be transmitted to the ear through a condensed atmosphere at such a pressure with the same facility as through the normal one, the pressure also affecting at the same time the sensi-

bility of the anditif nerve, but temporarily, as did the pain on the tympanis, after being a few minutes in the air-lock. We say temporarily, because after some time sojourn in the air-chambers this phenomena almost ceased.

After leaving the air-chambers or caisson and returning into the air-lock, in which *we remained six minutes*, during this time the temperature from 45° in entering it, fell to 34°; as the compressed air escaped and the equalization of pressure taking place with the normal atmosphere in the shaft, which we reached, and after ascending the circular stairs we returned to the surface of the pier.

We experienced, as before, *the same hard breathing and exhaustion, three or four times, in coming up*; our pulse after returning to the normal atmosphere was 92—88—90—95 per minute; the appearance of the entire party was very sallow.

Ten minutes after returning to the normal atmosphere, the author commenced to feel a severe epigastric pain, which was relieved by taking a table-spoonful of a cordial; on going home the pain left him completely, but there was a general feeling of great fatigue, which lasted about three hours, during which his pulse, from 92 per minute, fell to 81, its normal condition.

This concludes the second regular observation.

EAST PIER, February 19th, 1870—11 o'clock, A. M.

Barometer 29°, 36′. Thermometer 33°. Weather cloudy. Pressure thirty-seven and one half pounds to the square inch. Caisson eighty-one feet below the surface of the water.

There were six persons to go down in the caisson. The writer, three stranger visitors, and two working-men. Our ages were one forty-six, two thirty-two, and three from twenty-eight to thirty years old. The appearance of all was healthy, the complexion tolerably fair. Our pulse respectively was 81—75—76—80—76—82 per

minute. No measure of chest was taken having previously indicated no marked change in the several preceding observations.

After descending to the bottom of the shaft, seven of us, including the lock-tender, *entered the air-lock, where we remained twelve minutes and a half for the equalization of pressure with the air-chambers.* None of us felt any inconvenience during that time. When entering the air-chambers the temperature was 45°. Our pulses were 97—77—77—92—88—90 per minute. Our respiration was 21 per minute. The phenomena of alteration of the sounds in our speech was observed to a greater degree than on our preceding visit. We refer for the explanation of this phenomena to our last observation. (Page 22.)

After experimenting again on the temperature of ebulition, we obtained the following results:

For distilled water when in ebulition, in a red copper vessel, the thermometer was - - - 280°
When in ebulition in a glass one, - - - 284½°
For Mississippi river filtered water, in a red copper vessel, - - - - - - 277°
When in ebulition in a glass one, - - - 280°

The same falling of the thermometer was observed when the insulation of the platform ceased, by putting our hand on it, but rose again in a few seconds after withdrawing it. After remaining two hours in the air-chambers our pulse was 64—70—67—69—68—68 per minute.

Thinking that it was necessary to ascertain if there was any appreciable quantity of carbonic acid in the air-chambers, we experimented by shaking a large mouth glass jar containing about two pints of fresh slackened lime water, at different places and height in the caisson, but without noticing any effervesence or milky appearance in the lime water, which was, for the present, sufficient proof that if there was any carbonic acid pre-

sent it must be a very small quantity. But what became of the carbonic acid evolved by the respiration of the workingmen, or from any other cause, we will examine it hereafter.

Our experiments concluded, the thermometer was 45°. We then entered the air-lock to return into the normal atmosphere, and directed the lock-tender *to let the compressed air escape very slowly so as to enable us to remain at least seven minutes*, to return in the shaft or normal atmosphere.

During the seven minutes we were in the air-lock, while returning to the normal atmosphere, *the thermometer, which was* 45° *when we entered it, fell to* 32°, *giving us an uncomfortable sensation of cold*, which was only relieved by entering the shaft or normal atmosphere, where the temperature was 59°. Our pulse then was the same as in the air-chambers. After leaving the air-lock and during the time we were ascending the stairs in the shaft, *we had to rest at different times, breathing heavily, our pulse quickening, though not losing its strength.* Arrived at the surface of the pier, our pulse was respectively 104—90—90—100—94—96 per minute. Our appearance was very sallow and we felt much fatigued.

Ten minutes after reaching the surface of the pier, *I felt a very severe epigastric pain, which increased while crossing the river to the shore.* I then drank two tea-spoonsful of old Jamaica Rum which relieved me in a very few minutes, but the feeling of great fatigue and depression of the system, which I experienced on my preceding visit, remained during four and a half hours, compelling me to lie down until evening.

This concluded the third regular observation.

I intended to continue my experiments and observations on the 22d February, but since my last visit to the caisson, I was so feeble that I thought best to postpone them until I felt better and stronger, and that I would wait until the caisson had touched the rock.

EAST PIER, FEBRUARY 28th, 1870—11 o'clock, A. M.

Barometer 29° 60′. Thermometer 34°. Weather clear. Caisson touching the rock ninety-five feet below the surface of the river. Pressure forty-five pounds to the square inch.

Four of us went down, one forty-six, one thirty-four, one thirty-two, and one twenty-nine years old. Before descending the shaft our pulses were respectively 82—78—79—85 per minute. Our complexion was healthy and fair. Arrived at the bottom of the shaft the thermometer was 48°.

Four of us and the lock-tender entered the air-lock, *the compressed air was let in very slowly, still slower than on our preceding visit. It took fifteen minutes to equalize the pressure with the air-chambers.* Our pulses, after ten minutes in the air-lock, rose to 102—95—97—97. The thermometer, from 53° when we entered, rose to 68°. Our respiratlon was 21 per minute. On entering the air-chambers twenty minutes after, the thermometer was 45°; our pulses were respectively as before descending the shaft, 82—78—79—85. Our respiration continued 21 per minute. During our conversation the sonority of the voice was more affected than on our preceding visit. The caisson touching the rock, and being the deepest point to be reached, where it would be possible to experiment, I continued my observations on the temperature of ebulition under high pressure, with the following results.

Distilled water when in ebulition in a red copper vessel, thermometer, - - - - - - - - 294°
When in a glass one, - - - - - - - - 297°
Mississippi filtered water, in a red copper vessel, 291°
When in a glass one, - - - - - - - 294°

After having terminated our experiments, which lasted two hours in the air-chambers, the temperature was 45°; we felt well and were ready to return to the normal atmosphere, when MR. J. B. EADS, *happening to be in the air-lock with a party of visitors*, coming

down in the air-chambers, then *I remained with them three-quarters of an hour longer*, and going around in the several places where the caisson touched the rock, and I waited until they returned into the air-lock in order *to go with* them.

There were ten persons in the air-lock when the door of the air-chambers was closed; *the equalizing valve opening into the shaft or open air was freely opened*, the compressed air escaping very rapidly. I felt the same decrease of temperature as in my preceding visit, and I was taken with a violent pain in the head, in the region of the superior longitudinal sinus,—pain so violent at a time *that I asked* that the escape of compressed air might be lessened.

We were only three minutes and a half in the air-lock, to return into the shaft or normal atmosphere. I was the last to leave the air-lock, not feeling very well; and *after resting four times in ascending the stairs, I arrived at the surface of the pier, almost exhausted*, my pulse at 110 per minute. I sat down a few minutes, but did not feel any better. I was taken again with the same epigastric pain as in my former visit. I was dizzy, so that no sooner was I on board the boat which crossed us to shore than I had to sit down on the stairs of the cabin to prevent myself from falling; my pulse grew weaker, and after reaching the shore, I had to use great exertions to reach my buggy, only half a square distant. I succeeded in getting in. During that time the epigastric pain increased, having nothing to take to relieve me, an accident in the caisson having deprived me of my flask containing the cordial which I intended to use in case of necessity, if suffering as before from the same pain.

In the course of a few minutes I drove home, which I reached at half-past two o'clock P.M., *three-quarters of an hour after leaving the air-chambers or caisson.* The

last effort brought me to my office, where in a few minutes I became paralysed.

This concluded the fourth systematic regular observation.

Before proceeding farther, we must say that these successive experiments on ebulition of water under increased atmospheric pressure, which we made during our preceding visits in the air-chambers of the east caisson at the bridge, seem to have no relative interest with the subject we have undertaken; but when our readers find that a liquid like water can be influenced in its physical change from a liquid form to a gaseous one or steam, by the increased atmospheric pressure, and that then water is an inert body — if we found that increased atmospheric pressure exerts such influence on its physical transformation from a liquid form to a gaseous one, is it not rational to infer the influence of increased atmospheric pressure to a much greater degree on an organized body as the human system?

Therefore it was the reason we continued our researches by experiments on the ebulition of water under increased atmospheric pressure, and made also our observations on the physiological effects and on the pathological symptoms on the men working in the air-chambers in the caissons at the bridge.

CHAPTER III.

PERSONAL EXPERIENCE BY THE WRITER—TAKEN SICK AND PARALYSED AFTER COMING OUT OF THE CAISSON —HIS OWN PATHOLOGICAL OBSERVATIONS, TREATMENT, AND RECOVERY.

Being in my office paralysed and unable to speak for a few minutes, but conscious of what was passing around, I made signs to my wife and persons with her at the time not to move me at all, but to lower my head and to raise my feet as high as possible. In the course of a few minutes, I was able to articulate a few words, but with great effort, and to say what should be done to me. *I was to be left perfectly quiet on my back or my right side, my head on a level with my body, my legs stretched, and my feet elevated two feet above my head.*

Then I took a tea-spoonful of old Jamaica rum every five minutes three times in succession, and kept a small piece of ice in my mouth to quench my thirst. A few minutes after I commenced taking two large table-spoonsful of beef tea every five minutes. I was suffering from profuse cold perspiration, every effort to speak caused great suffering and fainting, my pulse was 106 per minute, both legs and my left arm were paralysed, still I was suffering in both with excruciating pains which I can only compare to pains felt after a fracture of the left leg, whlch I experienced some years ago. During the pains in my limbs, which increased at intervals, my pulse was 115 per minute.

I knew well that in my situation, as I said to my wife, that after doing all I directed to be done, if I was no better by half-past five o'clock that same evening that nothing more could be done.

About half an hour after reaching home, three o'clock P.M., my pulse was 100 per minute, but a little stronger; the pains were not so frequent, but as severe; it was impossible for me to move my legs and my left arm. Any attempt to remove my clothing occasioned fainting.

I directed that I should be left perfectly quiet, but from time to time to be turned only from my back on my right side, but with the greatest care, the least deviation of my body or any part of it increasing the intensity of my sufferings.

At half-past three o'clock P.M., I felt some better; my pulse was 100 per minute, but a little stronger. I was still taking beef tea every ten minutes, and kept using ice. The pains were not so frequent, but as strong, in the legs and left arm.

At forty-five minutes past three o'clock P.M., I felt sleepy, and dozed about ten minutes, after which I felt much better and stronger, but was still paralysed. The perspiration was still very profuse, but not so cold, and being very thirsty, I continued the ice. I commenced to be relieved of the pains in my limbs, and felt that I was gaining strength, my pulse being 96 per minute, and stronger. I slept about twenty minutes; and at half-past five o'clock P.M., three hours after reaching home, I was undressed and put to bed.

I had use only of my right arm, and noticed that *after being removed* to my bed *the paralysis had increased*, but this increase remained temporarily. Some time after I was in bed I felt more comfortable; my head was kept very low, my legs and feet were raised by pillows a foot above my head, and lying on my back or on my right side.

At six o'clock P.M., the profuse perspiration ceased; my pulse remained 96 per minute, but full, with symptoms of fever, which gradually increased until half-past seven o'clock P.M., at which time *I considered myself out of immediate danger*. The pains in the left arm

and both legs were less frequent. I had intervals of comparative ease. At half-past nine o'clock P.M., I commenced to move my legs a little, as also my left arm.

I had no disposition to sleep. At half-past eleven P.M., the pain had left my left arm, and I was able to move it; but the pains had located in both knees, and was so intense as to cause me to groan. My pulse was still 96 per minute and full; my skin hot but moist.

At half-past two o'clock A.M. I slept, but was awakened from time to time by the suffering when trying to move; after half-past three o'clock A.M. I commenced to move my legs. Shortly after four o'clock A.M. I slept, and did not awake until after seven o'clock A.M., when I was able to sit up in my bed, but felt very weak, my pulse being 92 per minute, and my skin warm and moist.

I had not any micturition since the preceding morning at ten o'clock, and in order to do so, it was only after trying four different times, that I succeeded in passing some very dark-colored urine, *but not bloody.*

After dressing I tried to walk. I succeeded, but it was only on a smooth floor. For more than two hours after, I could not raise my feet higher than four inches from the floor; for a week I was rather feeble, but after that time I recovered my strength rapidly.

This recital of my experience as a patient may seem to be lengthy. It is nothing else but what I experienced, and it was full of suggestions of what I would have to do if I was professionally called to attend similar cases.

CHAPTER IV.

PATHOLOGICAL SYMPTOMS OBSERVED AMONG THE MEN WORKING IN THE AIR-CHAMBERS—THE REMEDIES USED AS CURATIVE AND PREVENTIVE ARE INEFFICIENT.

During my preceding visits at the bridge before I was taken sick, and when the caisson at the east pier was fifty feet (50) below the surface of the river and fifteen (15) feet in the sand, the pressure 24 pounds to the square inch, *the men were working in the air-chambers six hours per day, two hours at a time, with two hours rest between each time of work*, when some of them commenced to complain of epigastric pain and cramps in the arms and legs, but principally in the legs. In most cases, after a few hours of rest, the pains disappeared, and the men returned to work. Some were taken again, and with increased violence; some were suffering with parepsis of both legs, which obliged the men so attacked to discontinue work for a day or more; and some were suffering from complete paraplegia, involving the bladder and rectum, which disabled them from any further work in the air-chambers.

By the advice of somebody, the men were ordered to wear a voltaic belt around the body, or a voltaic sole to be worn in each shoe or boot, between the sole and the foot, or two voltaic bracelets to be worn around each wrist, — the voltaic element being composed of a series of zinc and silver plates overlapping each other about one-eighth of one inch, said voltaic apparatus *intended as a preventive and cure for the pains the men who were working in the caissons complained of.*

During our visits to the bridge, we saw many of the men wearing *these voltaic apparatus, and by careful*

enquiry, we did not hear that much benefit had been derived from their use; for we saw men taken with very severe pains, who had been and were still wearing soles, belts, and bracelets, and were taken sick after coming out; and among them some became paralysed while wearing the apparatus, and some even died wearing them.

Again, some claimed that the "Magic Oil," a kind of patent liniment, was a sure cure for those pains and cramps caused by working in the air-chambers. It was used freely in frictions on the men as soon as they were complaining, but without any marked benefit.

Then another preparation called "King of Pains," claiming to operate wonderful cures on the pier patients (as the sellers of this nostrum were pleased to call the suffering men who had worked in the air-chambers) was also used—internally in small doses, and externally in large quantities—but without any more success than attended the voltaic plates or magic oil or liniment.

Magneto-Electricity, produced by a magneto-electric machine, was also tried on the men as soon as they complained, but no favorable or permanent result was obtained by its use in the cases which were subjected to it.

Warm baths and even hot baths were resorted to to relieve the sufferers, but with no marked benefit, except to stop for a while their pains; but as soon as they were removed from the bath, the pains returned; and some *were paralysed while in the bath, or immediately after.*

Notwithstanding all the attempts to prevent, cure, or relieve the sufferers, the number of cases increased daily. Cases of paraplegia occurred frequently, so that on February 15th, some of the men were actually sent to the city hospital.

CHAPTER V.

DEATH OF SOME OF THE MEN—INQUESTS BY THE CORONER —POST MORTEM EXAMINATIONS, AND OPINIONS OF SOME OF THE PHYSICIANS PRESENT AT THE INQUESTS.

The work of sinking the piers progressed, but the pressure increasing also in the air-chambers, the number of cases became more frequent, and as soon as a man was taken sick he was sent to the city hospital.

On the 21st March, 1870, twenty cases had been sent to the hospital; five died—two within a few hours after their admittance.

Inquests were held by the coroner, and post mortem examinations made.

Of those five post mortem examinations, *three are copied from the reports given by the coroner, and the two others from reports printed in the daily papers and medical journals*, which we here reproduce.

FIRST POST MORTEM EXAMINATION.

James Moran, 35 years old, *Ireland*, admitted in the hospital on the 10th March, 1870, died on the 19th of the same month, nine days after his admittance.

When sent to the hospital he had never been but two hours in the caissons.

The spinal column was first opened, in dissecting down to the dorsal muscles; the veins were found to be very numerous and distended, with dark and tarry blood. The vascularity signally increased with the approach to the spine.

On removing the vertebral arches, and exposing the dura mater, the cellular tissue exhibited great vascularity and reddish gelatinous infiltration. The dura

mater was separated from the spinal cord by a copious collection of serum, fluctuating on pressure, and changing its level in altering the position of the body.

The serum was not collected and measured, but was estimated at about two ounces. Leaving the spinal cord and its membranes in situ, we proceeded to the cranial cavity, and removed brain and spinal cord together.

The arachnoide membrane of both brain and cord was intensely vascular; its vessels of larger calibre; the structure succulent, and at various places of the brain changed in thickness and transparency, and covered with inflammatory products of a whitish-grey hue, besides being raised off by subarachnoide serous infiltration. The consistency of the substance of both organs was on that occasion but superficially inquired into, inasmuch as a microscopic examination is purposed.

In pressing on the spinal cord, some elastic resistance was observed, which proved to be serum in its canal, so much accumulated in that space that, being pressed from two opposite directions, it would distend the cord cylindrically. Near the cauda a moderately-sized vein was completely trombosed. (?)

The right side of the heart was filled with coagulated fibrine, which extended into the pulmonary artery; whereas the left side contained some blood of a dark appearance, not coagulated. The lungs were well inflated; anteriorly they were of normal color, but posteriorly darkened from hypostasis. The kidneys, slightly enlarged, showed venous congestion. There was hemorrhagic infiltration about the junction of the cortical and medullary substance. Ureters normal. About the bladder, and extending below the peritoneum backward and upward, there was extravasion of blood without any mechanical lesion. The bladder itself, although but containing a small quantity of

urine mixed with blood, was collapsed, and from previous distension far larger than usual. The mucous membranes thickened, softened, and discolored.

Intestines, liver, and spleen were marked by hypostatic conditions, with extravasion of blood.

SECOND POST MORTEM EXAMINATION.

G. S. ALT, 22 years; nativity, *Germany*; admitted in the hospital March 10th, 1870, after working two hours in the caissons; died, March 22d.

The brain and spinal cord were found highly congested, the latter being softened in many places to pulpy consistency. There was evident subarachnoid effusion, and probably more that that a normal quantity of fluid in the dura mater of the cord. Small clots of extravasated blood were found at different points on the external surface of the latter membrane. All the abdominal visceras were surcharged with blood, the lungs suffering less in this respect than any of the other organs. There were clots of blood found in both kidneys; one of the ureters was very much enlarged.

THIRD POST MORTEM EXAMINATION.

HENRY KRAUSMAN, 27 years; nativity, *Germany;* admitted in the hospital, March 22d; died 23d same month.

The whole contents of the cranium were found highly congested, with effusion beneath the arachnoid, the vessels of the latter membrane being highly injected. Blood oozed freely from the substance of the brain on section. The spinal cord presented pathological conditions precisely like those of the brain, with the addition of the existence of clots of extravased blood at different points inside of the dura mater; there was also a congested condition of the thoracic content, less marked probably in the lungs than in the other organs. The abdominal visceras were very highly congested,

with extravasion of blood in the kidneys. The mucous membranes of the bladder was healthy, and a small quantity of bloody urine was in the bladder.

FOURTH POST MORTEM EXAMINATION.

THEODORE LOUIS BAUM, 21 years; nativity, *Germany;* admitted in the hospital, 22d March, 1870; died, 23d same month.

On examining the contents of the cranium, the substance of the brain was found overcharged with blood, oozing freely from minute points on section. The meninges were also highly congested, and considerable serous effusion between them, most marked under the arachnoid. The spinal canal was also opened and examined, and about the same condition existed here as in the brain. The effusion under the dura mater was well marked. There was also found in the inside of the dura mater at several points small clots of extravased blood. In examining the thorax, the small capillaries of the pleura and pericardium were found highly injected. The lungs very highly congested, but much less than the other organs. All the abdominal visceras were intensely congested; clots of extravased blood were found in the kidneys, and small dark patches on the mucous membrane of the bladder, resembling ecchymosis.

FIFTH POST MORTEM EXAMINATION.

GEORGE BARROWS, 22 years; nativity, *United States;* admitted to the hospital the 1st of April; died the 12th.

The brain and spinal cord and its meninges were found congested, and with slight sub-arachnoid effusion. The thoracic visceras were found normal, except some slight adhesions of the pleura.

On opening the abdomen, the intestines and the peritoneum were found highly inflamed, with extensive adhesions between them. The bladder and rectum

were found gangrenous, the former having been perforated by ulcerations, discharging its contents of bloody urine into the peritoneum.

The opinions given on those cases by two medical gentlemen of this city, and who were present at the post mortem examinations, are literally copied as follows.

The first opinion given was *that the affection by which the laborers in the air-chambers are attacked is chiefly attributed to the change from a very condensed to a comparatively rarified atmosphere.*

Second Opinion.—"*In fact, I believe the greatest danger to persons entering the caissons is that they enter too rapidly; that if they would admit the pressure more moderately, so that the heart and internal organs accommodate themselves more gradually to this process of congestion.* And as to the manner of coming out of the air-lock, *I should think it advisable to come out as rapidly as possible; for in every case, whether they suffer or not, there must take place a certain degree of reaction to the surface of the body, which is only accomplished by the removal of the atmospheric pressure in entering the open air.*"

We will refer hereafter in our analysis to the opinions enunciated by those two medical gentlemen.

CHAPTER VI.

NUMBER OF CASES STILL INCREASE AMONG THE MEN—DEATHS AT THE PIERS—THE WRITER TAKES CHARGE OF THE MEN WORKING IN THE AIR-CHAMBERS—MODIFICATIONS IN THE DURATION OF TIME OF WORK PER DAY—SYSTEMATIC DIRECTION GIVEN FOR REMAINING IN THE AIR-LOCK.

No precise or even proximate cause of the pathological phenomena, based on facts, could be adduced, nor was any prophylactic means advised in order to avoid the recurrence of such cases.

In taking charge of the men, we found them as follows:

There were at the east pier 80 men working in the air-chambers, divided into gangs from eight to ten, with a foreman for each gang.

Their appearance was generally healthy and cheerful; their pulse ranged from 75 to 82 per minute.

Their nationality was nearly equally divided between United States, Ireland, and Germany, with the exception of five Frenchmen and four Englishmen. Their ages averaged as follows:—Five were from 17 to 20 years, fifty-three from 20 to 28, sixteen from 30 to 36, and six were over 40 years old. With a few exceptions their stature was rather below the medium height. Twelve were married. As a generality, they were intelligent, every one of them being able to read and write. As for their character, some were docile, easy to manage; some wilful and unruly.

Their habits were not very regular, except a few—many of them were using strong drinks rather too freely, and the most of them chewing tobacco. As to

their diet, a great part of the men were not taking a regular dinner, but going to shore, taking a lunch with one or two drinks, or even more, instead of a substantial but plain dinner.

When the writer took charge of the workingmen, there was at the east pier a flat boat, which had a cabin to receive temporarily the men taken sick.

This was immediately improved by large additions for accommodation, so that at least fourteen patients could be attended in the floating hospital. A room was also provided on the same boat, with berths for each man to rest during the interval allowed to them between their time of work in the air-chambers.

The duration of work was two (2) hours three (3) times a day, with an interval for rest of two (2) hours between each two (2) hours work.

Prior to the 31st March the men, as soon as they came out of the air-chambers, were allowed to go ashore, provided they were ready to return with their gang at their regular time of working in the air-chambers.

The appearance of the men when coming up into the open air was pallid and sallow; the pulse of some quick, ranging from 90 to 110 per minute; but with others it was the contrary—the pulse was as low as 60 per minute. All the men invariably in coming out of the air-chambers, after ascending the shaft, and once in the open air, complained of fatigue; but instead of resting by sitting or lying down, and keeping quiet for half an hour at least, they were running around and going to shore to take a drink or more. The consequence was, that when the time to return to the air-chambers approached, they hastened to the shaft to go down, and instead of being refreshed and to have recovered some strength, they were going down to work

again, in a condensed atmosphere, more exhaustive to human organism than any kind of work performed in the open air.

Such was the state of things when we took charge of the men at the bridge.

Having experienced ourselves the exhaustive power of a condensed atmosphere, very nearly equal to the pressure to which the men had to work—being 48 pounds to the square inch—we thought a change between the time of work was necessary, that is to say, we suggested that they should work six hours per day, divided into three watches of two hours each, but with three hours rest instead of two between each two hours of work.

We instructed also the air-lock tender (*the man in charge of the air-lock*) *for the duration of time* that the men had to stay in the air-lock when going to work in the air-chambers or when coming out of them. This had not been regulated, and had been left to the option of the air-lock tender; and it so happened that when the men were going to work, if they had with them *a new or green hand*, as they called him, they enjoyed the fun of letting the compressed air to come in very fast, *and instead of being sixteen* (*16*) *minutes in the air-lock*, when the pressure was 48 pounds to the square inch—*to equalize the pressure with the air-chambers or caissons—they were only five to six minutes*, which time was not only too short but injurious to some of them.

But it was still worse for the men themselves working in the air-chambers, when, after two hours working, and anxious to come out into the open air, they were *going through the air-lock still quicker*, *as for instance*, *in three or four minutes*, instead of seven or eight minutes, which time they ought to have remained.

Then we directed that *every air-lock tender* should always, when taking a gang of workmen and going

from the air-lock into the air-chambers, *should take one minute to every three pounds of pressure until the equalization between the air-lock and the air-chambers or caissons*,—that is to say, 16 minutes for 48 pounds pressure; and *when going out through the air-lock, from the air-chambers to the normal atmosphere, one minute to every six pounds*,—that is to say, eight minutes, to let the compressed air in the air-lock escape into the shaft and to return into the open air.

By my directions, every man working in the air-chambers who should be taken sick was to be removed immediately to the floating hospital at the east pier, to receive the necessary attendance, and *that under no circumstances should any one be removed from the pier to any other place*—having given special directions for the treatment of those taken sick during my temporary absence—being convinced, after the careful observation of some cases, *that any removal or transportation of the men taken sick aggravated their case*, and might in some cases involve life.

After increasing the time of rest between the two hours work, no case occurred until the 4th of April.

CHAPTER VII.

DECREASE OF FATAL CASES—SEVENTY-EIGHT CASES OF OBSERVATIONS AND TREATMENT—RECOVERY—SYSTEMATIC EXAMINATIONS OF THE MEN WORKING IN THE AIR-CHAMBERS—PROPHYLACTIC TREATMENT.

At the east pier, the pressure being increased to fifty (50) pounds to the square inch by the rise of water in the river, the men again commenced to suffer and complain; and I then observed that symptoms of exhaustion prevailed always on a man, when he complained of being sick, after coming out of the air-chambers. It was evident to me that the waste on the system of those men was going on faster when working in the air-chambers than on any other man working in the open atmosphere.

I observed also that when a man was taken sick immediately after coming out of the air-chambers his pulse was 95 to 115 per minute and feeble; but that the contrary happened on those taken sick after a lapse of twenty minutes or longer, their pulse being generally slow—very often as slow as 60 per minute. Either, when taken sick, was covered with cold profuse perspiration. The temperature of the body was not much changed, except the legs, which in most serious cases were cold and the skin clammy. The pupils remained unchanged, the face was pale and livid, and the lips discolored; but this, after from five to ten minutes, ceased after the patient had been lying down and at perfect rest, and his legs more elevated than the head.

After repeated observations of similar cases, I prescribed the following treatment, the success of which

will be demonstrated by the perusal of the first forty-nine cases which came under our care during a regular attendance at the bridge from the 31st March, 1870, until the 27th May following.

I directed that the *working men, as soon as they were coming up from the air-chambers*, should rest and keep quiet for an hour, and if any were taken sick the treatment was to be as follows:

The patient was to be put in bed lying on his back or right side, the head low—level with the body, the legs stretched, the feet elevated at least one foot above the head, and all clothing loosened.

I prescribed half an ounce of the following cordial, which always relieved the violent epigastric pains:

R.	Spiritus Jamaicensis, -	viii. fluid ounces.
	Syrupus simplex, -	iv. fluid ounces.
	Oleum anisi, - -	ii. fluid drchms.

After taking this cordial, and from five to ten minutes after, it was followed by two table spoonsful of beef tea (made with Liebig's extract of meat in the proportion of one drachm to six ounces of boiling water), two tablespoonsful was given from five to ten minutes; and as the patient always after a while complained of thirst, ice was freely used, but no water or any other drink was allowed for at least two hours.

The beef tea was continued regularly; the position of the patient was still adhered to; but afterward the legs were left in the most comfortable position, as soon as the pulse was getting stronger and less frequent, that is to say, for the cases where the pulse was over 95 per minute and feeble, and more frequent in the cases where the pulse had fallen as low as 60 per minute. Then, and not until then, was the patient allowed to change his position.

The necessity of placing the patient on his back, with the head low and the feet elevated, was to send more stimulus to the brain, and prevent a return of syncope,

which sometimes happened, and which, if repeated in a state of exhaustion, might have had a fatal termination. And when the position was alternately changed from the back to the right side, it was to relieve the spine, and at the same time the heart, to let it resume its regular function, which was more or less disturbed at the time the patient was taken sick. No bath of any kind was given to any of the sufferers, having been positively forbidden by me.

The first case which occurred after commencing my regular attendance at the bridge, was on the fourth of April, and was afterwards followed by others, as the data of observation in each case will show. I was unable then to control the men and persuade them to keep quiet and rest after coming up from their work, as also to prevent them from going ashore, where a great many were drinking freely, and, it will be seen, that before I got control over them, that is to say, from the fourth of April until the twenty-fifth of the same month, thirty cases occurred.

From repeated observations the variation of the temperature of the normal atmosphere did not seem to have any marked influence on the men working in the air-chambers, nor did the barometrical changes, as it was at first supposed, and this is the reason we have thought it necessary to note at the head of each case the state of the barometer, thermometer and appearance of the weather, as also the pressure then existing in the air-chambers.

CASE I.—APRIL 4TH.

East Pier. Barometer 29° 44′. Thermometer 50. Weather clear. Pressure forty-eight pounds to the square inch.

WILLIAM WILSON, twenty-two years; nativity, United States; medium stature; worked three weeks in the caissons; taken sick for the first time, after a two hours' watch, at eleven o'clock, A. M., two hours after coming up.

SYMPTOMS.

Face livid, pulse 66 per minute. Complained of violent epigastric pain, as also of shooting pains in back and left arm. There are manifest signs of paraplegia.

TREATMENT.

Half an ounce of cordial; kept at perfect rest in bed, in the position already prescribed; two table-spoonsful of beef tea every ten minutes; when thirsty, ice. Continued the same for one hour, after which, the pulse 70 per minute; beef tea every twenty minutes and kept at rest for one hour longer; the epigastric pain and pain in back nearly disappeared, and also the symptoms of paraplegia; motion has returned. Six o'clock P. M.; pulse 76 per minute; appearance good. Asks to go home by himself, which is granted. Rested two days, and recommenced work.

CASE II.—APRIL 5TH.

East pier. Barometer 59° 45′. Thermometer 60°. Weather clear. Pressure forty-eight pounds to the square inch.

G. LYONS. (Foreman.) Thirty years; nativity, Pennsylvania; worked nearly five months, and since the caissons were submerged; was taken sick after the third watch of two hours; said himself that he did not rest between the last two watches he worked the day he was taken sick. It was about twenty-five minutes after coming out of the air-chambers that he was taken with violent epigastric pain and parepsis of both legs. Being myself absent at the time, a hot bath was given to him to relieve the pains, of which he was free as long as he remained in the bath, but as soon as he was out of it he was taken with paralysis of both legs and left arm, and shortly after the pains returned.

He was sent home in an ambulance, within three-quarters of an hour after being taken sick. I saw the patient one hour or so after he was removed to his home. The patient was of medium stature, and well built.

SYMPTOMS.

Face pallid, pulse 64 per minute—paraplegia was complete. The legs were both cold and shrunken, and of cyanotic color; notwithstanding the paraplegia he was complaining of shooting pains in both legs and lower part of the back.

TREATMENT.

Perfect rest in bed in the position already described. The patient not having taken any food for nearly twelve hours, two ounces of beef tea was given every half hour for three hours, and then the same continued every hour for four hours, after which the patient felt better, the pulse being 69 per minute. He slept a little, but was awakened by shooting pains in the legs and back. The bladder, being also paralysed, had not been emptied of its contents since morning. After examination, finding the bladder very distended, I used a catheter and drew two pints of urine, which was highly colored, but limpid and not bloody.

5th April.—Patient better; pulse 70 per minute; slept, but still complained of violent epigastric pain, which ceased as soon as the beef tea was taken. The legs are in the same condition; the bladder being again full and paraplegia existing, he has to be catheterised three times every twenty-four hours. 6th April.—Patient same; pulse 75 per minute; slept well, and has no more epigastric pain; asks for something to eat, which is granted. Catheterism is used three times a day, during which time the quantity of urine passed is at least half a gallon, and of normal appearance. 8th April, Same; pulse 75 per minute; slept well; appetite good; the patient commenced to use the catheter himself to relieve the bladder three times every twenty-four hours, and drew the same quantity of water as before. April 9th.—Pulse 75 per minute; good appetite; catheterised himself three times. 10th.—Same condition; had no stool since he was taken sick. 11th.—Same; continued the use of the catheter three times a day. 10th.—Same;

pulse 75 per minute; slept well; appetite good, but no stool yet. Prescribed one enema with two pints of tepid water and two fluid drachms of tincture of assafædita, which, after its administration, produced a constipated evacuation. April 14th.—Patient better; pulse 76 per minute; skin soft and warm; the paraplegia partially ceased; patient feels whenever anybody touches his legs and feet, and is able to move them a little; he can urinate, but with difficulty. From the 14th until the 30th, there was no notable change in the state of the patient. May 1st.—Same; pulse 78 per minute; commenced to sit up; can move his legs more freely, but each motion is succeeded by involuntary tremor. May 3d.—Still improving until the 23d, when he was able to sit up in an easy chair, but for want of proper nursing had to be removed to St. Luke's Hospital to insure the necessary nursing. May 25th.—Removed to St. Luke's Hospital; still improving; urinates freely four or five times in twenty-four hours, but is obliged to use an enema every other day to produce an evacuation from the bowels. May 28th.—Still improving; sat up two hours at a time, three times a day. June 10th.—Pulse 80 per minute and strong; has a daily stool without enema. Commenced to stand on his feet and walk with some assistance. 24th.—Still improving; pulse 80 per minute; can walk by himself by using a chair as a support. 28th.—Commenced to use crutches and go around. July 8th.—Left the crutches and used two canes instead, and no longer needed to look at his feet when walking. 18th.—Same; intend to leave the hospital; improving, but slowly, and unable to walk without the use of two canes.

CASE III.—April 5th.

East pier. Barometer 29° 94′. Thermometer 60°. Weather clear. Pressure fifty pounds to the square inch.

H. Kellog, thirty years; nativi y, England; worked six weeks; was taken sick for the first time after the

third watch, and from twenty to twenty-five minutes after coming up. Patient of medium size, well built.

SYMPTOMS.

Face livid; pulse 66 per minute; complained of violent epigastric pain, also pains in both legs, which were moved with difficulty. Followed the same treatment as in case No. 1, and in six hours the patient was much better; pulse 78 per minute, when he was removed to his home. April 6th.—Slept well; pulse 80 per minute; felt much better, but weak; intends to rest a few days before working again.

CASE IV.—APRIL 5TH.

East pier. Barometer 29° 94′. Thermometer 60°. Weather clear. Pressure fifty pounds to the square inch.

JOHN YAGER, thirty-three years; nativity, Germany; worked three weeks; taken sick for the first time after the third watch, and twenty-five minutes after coming up. Patient is of medium stature and well built.

SYMPTOMS.

Face very livid, and covered with profuse perspiration; pulse 64 per minute; violent epigastric pain; also pain in both legs and left arm.

TREATMENT.

Same as case No. 1 during one hour, after which the pulse is 70 per minute. Continued beef tea every half hour for six hours longer, when the pulse is 76 per minute, and the pains in both legs and left arm have ceased. Twelve hours after having been taken sick, he was able to go home by himself, but he remained weak for sometime, preventing him from returning to the same work.

CASE V.—APRIL 6TH.

East Pier. Barometer 29° 88′. Thermometer 63°. Weather clear. Pressure fifty pounds to the square inch.

CHARLES LOVEJOY, (foreman,) thirty-three years; nativity, United States; worked three months in the

caissons ; had suffered three times before of pains in his legs, principally in the knees, of which he recovered easily, and recommenced work the following day. This time he was taken sick after the third watch, and half an hour after coming out of the air-chambers.

SYMPTOMS.

Suffered with violent epigastric pains, and of slight paraplegia ; notwithstanding the marked state of paralysis the patient was complaining of shooting pains in both legs ; face palid, and covered with profuse perspiration ; pulse 66 per minute.

TREATMENT.

Same as case No. 1, during an hour, after which the pulse was 72 per minute ; continued beef tea every half hour for four hours longer and used ice, the patient being thirsty ; perfect rest for eight hours from the time he was taken sick, when he was sent home. Saw him the following morning : pulse 80 per minute ; felt well, but weak ; did not think him fit to work any longer in the caissons, and had him removed to some other work.

Notwithstanding all the care taken, having had five new cases in the last two days, of which case II. was a very serious one, *it became necessary to reduce the duration of time of work to two watches of two hours each, with four hours rest between each two hours work, making only four hours for a day's work*, and this only every twenty-four hours. But it availed us little, as it was impossible to keep the men at rest *after coming up from the air-chambers*, as they would still run around or go ashore to indulge in drinking. Immediately after their last watch was over, the majority of them, instead of taking time to rest or wash themselves, were running for the boat to go ashore, where, instead of going home to keep quiet and rest, the most of them were wasting their time of repose in bar-rooms or other places unfit for any man employed in such exhausting work.

We were convinced that it was necessary for strict regulations to be enforced to prevent among the men an increase of new cases, and that a favorable result could only be obtained by compelling them to take more regular and systematic rest between their time of work—*rest indispensable for repairing the waste caused on their organism by working in the highly condensed atmosphere of the air-chambers*—but to enforce these rules and regulations for their own benefit was next to impossible. All we could do was, when new cases occurred, to try our best to relieve the sufferers. On the following day we had—

CASE VI.—APRIL 7TH.

East pier. Barometer 29° 80′. Thermometer 60°. Weather cloudy. Pressure fifty pounds to the square inch.

CHAS. DUFOURNY, forty-four years; nativity, France; worked four weeks; was taken sick after the last watch, immediately after coming up; tall, slender build.

SYMPTOMS.

Face livid; lips discolored; skin cold and covered with profuse perspiration; pulse 110 per minute and feeble; complained of violent epigastric pain; also, of shooting pains in both legs.

TREATMENT.

Perfect rest, in same position as before described; given half an ounce of cordial, followed, five minutes after, by two ounces of beef tea, continued every ten minutes for an hour, after which the pulse was 90 per minute; continued the beef tea every hour during six hours longer, when the pulse was 85 per minute, and the patient felt well enough to be sent home; following morning felt well. After examination found him unfit for working in the air-chambers, and he discharged accordingly.

By the following case (7) it will be seen how difficul it was to enforce the regulations:

CASE VII.—APRIL 8TH.

East pier. Barometer 29° 88′. Thermometer 60°. Weather cloudy. Pressure fifty pounds to the square inch.

LOUIS BOYER, twenty-four years; nativity, France. This patient had only worked two hours for the first time, on the first of April, when he was taken sick with epigastric pain and parepsis of both legs, half an hour after coming up from the air-chambers. After resting a few days he intended to return to the same work, but before doing so, and after I had examined him, I told him not to go into the caissons any more, because he was unfit for such work. Notwithstanding my advice, he came with a friend the following morning to work in the air-chambers, and was taken sick the same day after the second watch, and after coming out of the air-lock. Instead of taking him to the floating hospital to receive proper treatment, he was removed to his boarding house by the same friend with whom he came to work in the morning. I saw the patient only six hours after his removal and found him as follows; tall but very slender.

SYMPTOMS.

Face hot; pulse 96 per minute. Paraplegia had supervened during his removal to his home. The bladder was full and distended; the catheter was used, and over half a gallon of urine of a dark color but clear, and containing no blood, was drawn. After the catheterism he felt much relieved, and in less than twenty minutes his pulse fell to 90 per minute. The thirst being very great ice was kept in the mouth, and two ounces of beef tea was given every hour. Catheterism was used again late in the evening, which drew the same quantity and quality of urine.

April 9th.—The patient has not slept, and suffered in the night of shooting pains in the back and both legs,

which are still paralysed, cold and shrunken; toward morning the water had to be drawn; the quantity had slightly diminished; the catheter had to be used twice in the day; the patient was restless, and the pulse 95 per minute.

April 10th.—Patient more restless; pulse 98 per minute; no appetite; skin hot and dry; catheterism used again. There being no suitable accommodation for a sick person he was removed to St. Luke's Hospital to remain under my care. 6 o'clock, P. M. Same; pulse 95 per minute; continued the use of the catheter.

April 11th.—Felt worse; had a chill in the night, which was followed by strong fever; pulse 110 per minute and full; paraplegia still existing; had to be catheterised during the night, the filling up of the bladder causing such violent pain that from this time the catheterism had to be used every eight hours regularly.

April 12th.—Had fever; pulse 100 per minute and full; no appetite, but a parching thirst; catheterised every eight hours and given a teaspoonful of spirit of nitre with two tablespoonsful of water every two hours.

April 13th.—Pulse 100 per minute; slept better; no appetite; same thirst; catheterised three times a day; continued the spirits of nitre every two hours.

April 14th.—Better; slept well; pulse 85 per minute; but the urine drawn in the night contained a large quantity of pus, which settled at the bottom of the vase. Bowels not evacuated since taken sick; prescribed an enema with two fluid drachms of tincture assafætida and two pints of tepid water, which, after administration, produced a large evacuation. Since last night the patient can feel and move his legs a little; catheterism is still necessary every eight hours.

April 15th.—Better; pulse 85 per minute; appetite returning; thirst ceased; had two involuntary stools: urine is drawn three times a day, each time containing a large quantity of pus. The quantity of urine in twenty-four hours, has been seven pints by measurement, even more, since the 11th.

April 16th.—Pulse 85 per minute; slept well; good appetite; felt and moved his legs better; catheterism still used three times a day.

April 17th.—Same, but moved both legs more freely.

April 18th.—Has been restless all night; pulse 90 per minute; had two involuntary stools, and felt a desire to urinate, but without success. Continued the catheterism three times every twenty-four hours. The urine, containing a larger quantity of pus than before, has become very fœtide, principally immediately after being drawn.

April 19th.—Pulse 85 per minute; same feeling of urinating, but without any result; catheterism still continued every eight hours; same quantity of pus in the urine as before, and urine very fœtide.

April 20th.—Patient better; slept well; pulse 82 per minute; good appetite; the pains in the legs have ceased, and he moved them freely; same feeling to urinate, but still obliged to have recourse to catheterism every eight hours.

April 21st.—Pulse 85 per minute; has urinated himself twice during the night.

April 22d.—Pulse 90 per minute; skin clammy; urinate freely, but the fœtidity of the urine has increased, and is becoming ammoniacal, besides still containing a large quantity of pus. Then I prescribed to take a teaspoonful every six hours of the following mixture:

Spiritus camphoræ, Spiritus nitri dul.,	each ii. fluid drachms.
Lupulina, - - - - -	i. drachm.
Mucilage accaciæ, - - -	ii. fluid ounces.

April 23d.—Pulse 84 per minute; urinated every three or four hours; the bowels are regular; appetite good; continued the mixture every six hours.

April 24th.—Pulse 80 per minute; felt better; continued the same.

April 25th.—Pulse 80 per minute, but urine containing still more pus, and very fœtide.

April 26th.—Pulse 90 per minute; more pus in the urine; emptied the bladder with a large silver catheter, then washed the bladder with a very diluted solution of carbolic acid, in the proportion of two fluid drachms of the solution of carbolic acid for half a pint of tepid water.

April 27th.—Pulse 85 per minute; urine better, but still containing a great deal of pus; repeated the same washing of the bladder morning and evening.

April 28th.—Pulse 85; slept well; urinated only every four or five hours, but there is still some pus in the urine; pumped the bladder with a great deal of care, and washed it by injection of the same solution of carbolic acid used since the 26th.

April 29th.—Pulse 85; less pus in the urine, which is clear, and, after settling, does not decompose so readily; appetite good; slept well; the legs have recovered their regular motion.

April 30th.—Pulse 85 per minute; feels better, and good appetite; pumped the bladder and washed it again with the same injection as used before, and which, when drawn, was colored with a small quantity of blood.

May 1st.—Pulse 85 per minute; patient feels weak, which I attributed to the successive injections of the bladder; had no stool for four days; prescribed a pill three times a day, containing one and a half grain of quinine with one grain extract of rhubarb.

May 2d.—Pulse 82 per minute; urinated about every two hours; great deal less of pus in the urine.

May 3d.—Pulse 82; slept well; can sit up; urine better, and pus still diminishing; continued the pills three times a day.

May 4th.—Same; improving, and urine without pus.

May 5th and 6th.—Same; no pus perceptible in urine, only after it had settled for some hours; bowels regular.

May 8th. Pulse 80 per minute; slept well; good appetite; feels stronger.

May 10th.—Same; improving fast; can stand up for the first time since taken sick; no pus in the urine, even after settling.

May 12th, 14th, 16th, 18th.—Same; slept well; voracious appetite; bowels regular; urine clear and natural.

May 20th.—Same; improving; commenced to walk.

May 22d.—Still improving; pulse 82 per minute.

May 25th.—Same.

May 28th.—Same.

May 31st.—Pulse 80 per minute; improving; urine clear and normal; bowels regular.

June 1st.—Same; walked out doors, a distance of three squares, for the first time since his admittance in the hospital.

June 4th. Same, and repeated his walk.

June 6th, 8th, 10th, 12th.—Walks every day to gain strength.

June 20th.—Feels well; pulse 81 per minute; discharged from St. Luke's Hospital, and will resume work in a few days.

CASE VIII.—April 8th.

West pier. Barometer 29° 70′. Thermometer 62°. Weather cloudy. Pressure forty pounds to the square inch.

E. S. Johnson, thirty years; nativity, United States; worked three weeks; was taken sick about twenty minutes after coming out of the air-chambers, and after the first watch of two hours; said he had not taken any breakfast. The patient was of medium stature and well built.

SYMPTOMS.

Face sallow; complained of violent epigastric pain, and parapsis of both legs and left arm; pulse 68 per minute; felt drowsy.

TREATMENT.

Same as case I.; after one hour's rest pulse was 72 per minute; continued the beef tea every half hour for three hours longer, after which the pulse was 75 per minute; kept him at perfect rest for six hours longer, when he was sent home.

April 9th.—Patient well, but will need a few days rest before recommencing work.

CASE IX.—APRIL 9TH.

East pier. Barometer 29° 70′. Thermometer 58°. Weather cloudy. Pressure fifty pounds to the square inch.

JOHN KELSEY, thirty-six years; nativity, Ireland; worked three weeks; was taken sick for the first time after the second watch, and immediately after coming up; above medium stature, well built.

SYMPTOMS.

Face livid; pulse 115 per minute and feeble; body covered with profuse perspiration; paresis supervened as soon as taken sick.

TREATMENT.

Same as case I.; after one hour pulse 90 per minute; continued the beef tea every hour for four hours longer, after which the patient felt better; pulse 85 per minute and stronger; moved his legs; kept all night at perfect rest, and on the morning of April 10th was improving, but felt weak; slept well; pulse 85 per minute. Sent him home and cautioned him against going into the air-chambers, as he was unfit for such work.

CASE X.—APRIL 9TH.

West Pier. Barometer 29° 70′. Thermometer 58°. Weather cloudy. Pressure forty pounds to the square inch.

GEORGE HARRIS, twenty-five years; nativity, United States; worked but three days, and was taken sick half an hour after coming up from the last watch of two hours. Patient of medium stature, well built.

SYMPTOMS.

Face livid, and covered with profuse perspiration; pulse 60 per minute; complained of violent epigastric pain.

TREATMENT.

Half an ounce of cordial, repeated after five minutes, and followed by two ounces of beef tea every ten minutes; perfect rest in the position already indicated; continued the beef tea for two hours, when the pulse was 98 per minute; continued the same treatment for two hours longer after which pulse 72; kept him at perfect rest all night.

April 10th.—The patient feels well, his pulse being 78 per minute, and he is able to go home.

CASE XI.—April 9th.

East pier. Barometer 29° 70′. Thermometer 58°. Weather cloudy. Pressure fifty pounds to the square inch.

G. M. McCartey, twenty-four years; nativity, Ireland; worked about two weeks; taken sick after the second watch, and immediately after coming up. The patient is of medium stature and well built.

SYMPTOMS.

Face livid, and covered with profuse perspiration; pulse 100 per minute; complained of violent epigastric pain, and paresis of both legs.

TREATMENT.

As before for one hour; pulse then 72 per minute and stronger; continued the same for two hours, when pulse 87 per minute; patient complaining of great thirst ice was used; kept him at perfect rest three hours longer, when the paresis disappeared, and he was able to move his legs quite freely. After remaining quiet two hours longer, feeling well and stronger, he was able to go home.

CASE XII.—APRIL 9TH.

East Pier. Barometer 29° 70′. Thermometer 58°. Weather cloudy. Pressure fifty pounds to the square inch.

HANSEP MILLER, twenty years; nativity, Germany; worked nine weeks; taken sick after the second watch, and immediately after coming up. The patient is of medium stature, slenderly built.

SYMPTOMS.

Face livid; lips discolored, pulse 110 per minute and feeble; complained of violent epigastric pain, which caused him to faint twice.

TREATMENT.

Half an ounce of cordial, repeated after five minutes, and followed by two ounces of beef tea every ten minutes for one hour; perfect rest, and after one hour, pulse 94 per minute and stronger; patient being much better, *I left him, directing what was to be done* until my return; but fifteen minutes after my departure, feeling shooting pains in both legs, *he demanded that a hot bath should be given to him, and, notwithstanding, that I had forbidden that a bath of any kind be given to patients, it was done.* After remaining about five minutes in the bath, he became paralysed in both legs and left arm, in which state I found him on my return, after an hour's absence. His pulse was 92 per minute, and despite the existing paraplegia, he was complaining of shooting pains in both legs and back. He had not passed any urine since 11 o'clock, A. M., and was suffering from its accumulation in the bladder. Catheterism had to be used which drew about one pint and a half of a highly colored but clear urine. The beef tea was continued every two hours during the night, as well as ice, the patient complaining of great thirst.

April 10th, 6 o'clock A.M.—Pulse 90 per minute; slept a little, but was awakened by epigastric pain, returning from time to time. Catheterism had to be used to empty the bladder, which contained two pints of dark

but clear urine. Seeing no prospect for this patient to improve for the present, he was removed to his home.

April 11th.—Same state; pulse 85 per minute; catheterism morning and evening.

April 12th.—Pulse 84 per minute; slept well; same state of the paraplegia.

April 13th.—Same; pulse 84 per minute; catheterism twice a day.

April 14th, 15th, 16th, and 17th.—Same; had no stool since taken sick. Prescribed an enema with two drachms of tincture of assafœtida and two pints of tepid water, which, after its administration, was followed by a large evacuation.

April 18th.—Pulse 84 per minute; appetite good; slept well, but no change concerning the paraplegia. The catheterism of the bladder had to be repeated twice a day. From this day until the 28th there was no change, but on the morning of the 29th, when turned on his right side, the urine contained in the bladder escaped involuntarily. It happened also on the morning of the 29th, before seeing him; and to satisfy myself that the bladder was really empty, I introduced a catheter, but without drawing any urine.

May 1st.—Pulse 80 per minute; appetite good; could turn in bed by using his arms, but there was no favorable change in the paraplegia. From the 3d May until the 21st, the patient remained in the same condition. On the 24th, 27th, and 30th, a current of magneto-electricity was used once, and then twice a day, but without producing any result.

June 2d.—Pulse 80 per minute; same state; the patient asked to be removed to St. Luke's Hospital, so that he might remain under my care. From the day of his removal until the 15th, there was no change. The pulse was 85 per minute and weak; and notwithstanding the constant care taken to turn him from side to side, large gangrenous sores appeared in the region

of the sacrum, and on both trochanters. Solution of carbolic acid was used for dressing, and I prescribed one grain of quinine to be taken every six hours, and beef tea and wine to be taken every three hours regularly.

From June 16th until the 21st, same; pulse 84 per minute; the sloughing of the bed sores well circumscribed; the solution of carbolic acid continued for dressing; quinine, wine, and beef tea continued.

From the 22d until the 28th June, no change; but involuntary tremors are observed in both legs if the patient was even slightly moved.

June 29th.—Involuntary stools commenced, and as often as four times a day. Fifteen drops of tincture of opium was given every six hours, but without any result.

June 30th.—The tincture of opium continued; the pulse is 92 per minute; patient taken with vomiting, which is stopped only with sparkling soda water; the tincture of opium discontinued.

July 1st.—Patient somewhat better; vomiting ceased; pulse 85 per minute; the involuntary tremor in both legs has ceased.

July 2d.—Pulse 84 per minute; no appetite; the incontinence of urine is still persisting, as also the involuntary stools. The legs are still paralysed. From this day until the 27th, the state of the patient has remained the same. On the 28th, the patient was desirous of returning home, and was removed on the 29th.

July 29th.—Visited the patient; pulse 80 per minute; heathy granulations forming on all the bed sores, which were discharging a healthy pus; no marked amelioration in the paraplegia.

July 30th.—Same; the tremor in the legs has reappeared, and there is no amelioration in the state of the patient.

CASE XIII.—APRIL 11TH.

East pier. Barometer 29° 79′. Thermometer 67°. Weather clear. Pressure 50 pounds to the square inch.

OLIVE ANDERSON, 27 years; nativity, United States; worked about two weeks; was taken sick after the last watch of two hours, about twenty minutes after coming up; above medium stature and well built.

SYMPTOMS.

Face pale, pulse 65 per minute, complained of violent epigastric pain, and feeling very weak.

TREATMENT.

Same as before for two hours, after which the patient felt much better; the epigastric pain ceased; pulse 80 per minute; kept him at rest for three hours longer; after which he was allowed to go home.

CASE XIV.—APRIL 11TH.

West Pier. Barometer 29° 79′. Thermometer 77°. Weather clear. Pressure 40 pounds to the square inch.

PHILIPS BRYAN, 27 years; nativity, Ireland; had never worked in the caissons before, and was taken sick after the second watch of two hours, and twenty minutes after returning to the open air; tall, but slenderly built.

SYMPTOMS.

Face pale, and covered with profuse perspiration; pulse 68 per minute; complained of violent epigastric pain, and paresis of both legs.

TREATMENT.

Same for two hours, after which the pulse was 75 per minute, the epigastric pain nearly ceased, and the legs nearly free from paresis. Kept him at rest six hours longer, after which pulse 78 per minute, and felt well enough to go home; but after examining him before leaving, he was found unfit to work in the air-chambers, and is accordingly discharged.

CASE XV.—APRIL 11TH.

West Pier. Barometer 29° 75′. Thermometer 75°. Weather clear. Pressure 40 pounds to the square inch.

WILLIAM SCHULTZ, 32 years; nativity, Germany; worked four weeks, and had suffered three times before of slight epigastric pains, but after half a day's rest returned to work. He was taken sick this time after the last watch, and three quarters of an hour after coming up, and having already returned home, where I saw him. He is of medium stature and slenderly built.

SYMPTOMS.

Face pale; complained of epigastric pain, and of parapsis of both legs and left arm; pulse 69 per minute.

TREATMENT.

Same; twelve hours after the pulse was 82 per minute, but weak; the parapsis has ceased. After examination, finding him unfit for working in the air-chambers, he was advised not to return to the same work.

CASE XVI.—APRIL 11TH.

West Pier. Barometer 29° 75′. Thermometer 67°. Weather clear. Pressure 40 pounds to the square inch.

PATRICK HENLEY, 28 years; nativity, Ireland; had never worked in the caissons before, and was taken sick after the first watch of two hours, and about twenty minutes after coming up. Above medium stature, and well built.

SYMPTOMS.

Face livid, and covered with profuse perspiration; pulse 60 per minute; had had, within a few minutes, two *syncopes*, from which he recovered, his face having been bathed with ice water, and by lying in bed with his legs stretched and his feet elevated above his head; he complained of violent epigastric pain and paresis of both legs.

TREATMENT

As before during one hour, after which the patient felt better; pulse 70 per minute; continued the beef tea every half hour, and the use of ice. After three hours' rest, from the time he was taken sick, the pulse rose to 78 per minute, and paresis ceased; kept him all night at the floating hospital, and on the following morning, (April 12th,) his pulse was 80 per minute and strong; he felt well enough to go home by himself.

CASE XVII.—APRIL 12TH.

West pier. Barometer 29° 85′. Thermometer 62°. Weather clear. Pressure forty pounds to the square inch.

JAMES ANDREWS, twenty-eight years; nativity, Denmark; had never worked in the caissons before; was taken sick after the first watch of two hours which he had ever worked, and immediately after coming up; was carried to the hospital in an insensible condition. The patient is of medium size and well built.

SYMPTOMS.

Face livid and swollen; lips discolored; pulse 110 per minute and very feeble; both legs and the left arm completely paralysed; the whole body was covered with a cold and profuse perspiration.

TREATMENT.

Half an ounce of cordial, repeated every five minutes for three times, and followed by two ounces of beef tea every ten minutes; perfect rest in the same position as before described during one hour, when the pulse was 95 per minute and a little stronger; continued the beef tea every half hour for three hours longer; pulse then 85 per minute, and the patient able to speak for the first time since he was taken sick. Upon questioning him, he said that he had been drinking very freely for the last year, but was sober this day before going into the air-chambers. During the following six

hours there was no change in his condition, and retention of urine existing, catheterism was used and two pints of dark colored, but not bloody, urine was drawn.

April 13th.—Condition of the patient still the same; same pulse; catheterised twice a day.

April 14th, 8 A. M.—There being no prospect of improvement for the present in the condition of the patient, he was removed to St. Luke's hospital.

April 15th.—Same condition; slept a little; very little appetite and weak; pulse 85 per minute but feeble; catheterised morning and evening, and the quantity and quality of urine drawn the same; prescribed as diet beef tea, milk, eggs and wine.

April 16th, 17th, 18th, 19th.—Same; pulse 85 per minute but still feeble; catheterised every six hours, the patient complaining of violent pain as soon as the bladder became a little distended; had no stool since he was taken sick; prescribed an enema with two drachms tincture assafætida and two pints tepid water, which, after its administration, produced a large evacuation.

April 20th, 21st, 22d, 23d, 24th.—Same condition; patient weaker; still catheterised every six hours; had no stool since he had an enema, which was repeated and followed by a large evacuation.

April 25th.—Pulse 90 per minute and feeble; had an involuntary stool in the night, and incontinence of urine supervened instead of retention; patient very weak; no appetite, and very thirsty.

April 26th, 27th, 28th, 29th.—Same condition.

April 30th.—Pulse 100 per minute and very feeble; incontinence of urine and involuntary stools became more frequent. Large gangrenous sores have commenced on the sacral region and on both trochanters, notwithstanding all the care taken to turn the patient from side to side every two hours, and to keep him as clean as possible.

May 1st.—Pulse 110 per minute and weak; the bed sores spreading, and the general appearance indicates that the patient is sinking.

May 2d, 3d, 4th, 5th, 6th.—Same; pulse 120 per minute; patient sinking very fast.

May 7th.—Died at 7 o'clock, A. M.

Post mortem examination held ten hours after death.

Cranium. The vessels of the pia mater were full and distended. There were extensive adhesions of old standing, said adhesions between the fold of the dura mater, descending in the interlobular fissure separating the two hemispheres of the brain. The brain, on inspection, was found healthy and firm to the touch, but two ounces of serum was found in the ventricules. The spinal column was not opened, but two ounces of serum was collected while escaping from the vertebral canal when removing the brain.

The Heart. The right ventricle contained a fibrinous clot extending to the pulmonary artery; the left ventricle contained fibrous clots and a bloody clot, and some two ounces of a dark liquid. The liver was of normal size, but of a slight nutmeg color. The spleen was four times as large in all proportions as in the normal state, but of normal consistence. The lungs were normal, well inflated, but there were adherences to the chest around the base of the right one. The kidneys were both larger than usual, the right one being the largest; both were soft, and the upper part of the parenchyne of each had a gangrenous patch of the size of a silver half dollar. The chalices contained no pus; the urethers of both were enlarged near their entrance to the bladder. The bladder was contracted and contained some pus, and the walls were thicker than usual; there was no enlargement of the prostate gland. The stomach was apparently normal, but contained about a pint of greenish liquid. The ileum and jejunum were slightly congested.

CASE XVIII.—April 12th.

West pier. Barometer 29° 85′. Thermometer 72°. Weather clear. Pressure forty pounds to the square inch.

Hugh Devel, twenty-eight years; nativity, United States; worked in the caissons only from the morning; taken sick after the second watch, and about twenty minutes after coming up; above medium stature.

SYMPTOMS.

Face pale, and covered with profuse perspiration; pulse 64 per minute and weak; complained of epigastric pain, and of paresis of both legs.

TREATMENT.

Same for one hour, pulse then 72 per minute; continued the beef tea every half hour; kept at perfect rest for two hours, when the pulse is 76 per minute and stronger; the paresis of both legs has ceased; was kept all night at the floating hospital, and on the following morning was much better; pulse 80 per minute and good; was able to go home without assistance.

CASE XIX.—April 12th

East Pier. Barometer 29° 85′. Thermometer 72°. Weather clear. Pressure fifty-two pounds to the square inch.

G. Donelly, (foreman,) thirty-two years, nativity, Ireland; worked three months; had epigastric pains three times; he recovered each time and resumed work after a day or two's rest. This time, when taken sick was after the last watch, and half an hour after coming up; of medium stature and slenderly built.

SYMPTOMS.

Face livid; complained of violent epigastric pain and paraplegia; pulse 65 per minute and weak.

TREATMENT.

As before for one hour, after which, pulse 70 per minute and stronger; rest for two hours when the pulse

is 75 per minute; could move his legs a little, and the epigastric pain left him; kept him at perfect rest until the following morning.

April 13th.—The patient much better; pulse 80 per minute; can move his legs better but not freely.

April 14th.—Pulse 80 and good; paraplegia completely ceased.

April 15th.—Much better and sitting up. After resting a few days he had entirely recovered.

CASE XX.—APRIL 14TH.

West pier. Barometer 29° 60′. Thermometer 80°. Weather clear. Pressure forty pounds to the square inch.

GEORGE HAAS, twenty-five years; nativity, Germany; had worked only three days in the caissons; was taken sick after the last watch, immediately after coming up. He is above medium stature and slenderly built.

SYMPTOMS.

Brought to the hospital in a syncopal condition, before which, he said, he was suffering of epigastric pain. Face livid, and covered with cold perspiration; pulse 110 per minute and feeble; paraplegia had supervened when brought to the hospital.

TREATMENT.

Same treatment was followed for one hour; pulse 94 per minute and a little stronger; continued the beef tea every half hour with rest for two hours longer, when the pulse was 88 per minute and the paraplegia partially subsided, although he still complained of shooting pains in both legs; kept him all night at the hospital. The following morning his pulse was 84 per minute; the paraplegia had subsided; could move his legs; still felt weak, but was able to go home.

At the East pier, on April 13th, about 5 o'clock A. M., a break happened in the coffer-dam, above the caisson, and was caused by the rise of water in the river, the water rushing in the main or central shaft leading to

the air-lock and air-chambers; the work was interrupted and all the men working therein were transferred to the West pier, where the men were not yet under our care for prophylactic treatment, and were still working three watches of two hours each, making six hours work every twenty-four hours.

A number of cases happened at the West pier, where up to April 15th, no reduction in the duration of time of work had been made; it being supposed that the pressure being less, the men working in the air-chambers were able to stand it better.

But we were of a different opinion, having had some very serious cases from the West pier, and we suggested a reduction of the time of work from two hours three times a day to two hours twice a day, with four hours rest between each two hours work. Notwithstanding this change, some men were taken sick after working one or two watches only in the air-chambers, but we must say that *those men had not been examined by us before commencing to work, and notwithstanding the positive directions and orders* which had been given not to allow any new man to go to work in the air-chambers without being examined by the physician, and to be declared in a fit condition for such work.

To avoid useless repetitions hereafter, we will be as brief as possible in epitomising the following cases, and will give details only, when we think a case requires it.

CASE XXI.—April 14th.

West Pier. Barometer 29° 60′. Thermometer 80°. Weather clear. Pressure 40 pounds to the square inch.

F. Tarbeaux, 35 years; nativity, United States; had worked three weeks, and suffered twice before of pains in both legs; but after resting a day or so he recovered, and went to work again. This time he was taken sick immediately after coming up.

SYMPTOMS.

Epigastric pain and parapsis of both legs immediately after coming up; pulse 98 per minute and feeble.

TREATMENT.

Similar as in other cases was followed, and after six hours his pulse was 80 per minute and good; the parapsis had subsided, and he was able to be sent home. After resting four days he returned to work.

CASE XXII.—APRIL 14TH.

West pier. Barometer 29° 60′. Thermometer 80°. Weather clear. Pressure forty pounds to the square inch.

AUGUST MILLER, 25 years; nativity, Germany; had worked only two hours in the air-chambers; was taken sick after the second watch, and immediately after coming up; of medium stature, slenderly built.

SYMPTOMS.

Complained of epigastric pain and parapsis of both legs; pulse 100 per minute.

TREATMENT.

The same treatment was followed as in similar cases, and after six hours he felt better; pulse 88 per minute; kept all night at the floating hospital; following morning pulse 82 per minute; parapsis subsided; felt well but weak and was able to go home.

CASE XXIII.—APRIL 16TH.

West pier. Barometer 29° 70′. Thermometer 43°. Weather cloudy. Pressure forty pounds to the square inch.

AUGUST TOMPKINS, 30 years; nativity, United States; worked two months; had suffered once of pain in both legs; this time he was taken sick after the last watch, 20 minutes after coming up; tall and slenderly built.

SYMPTOMS.

Violent epigastric pain, and parapsis of both legs; face livid; pulse 68 per minute.

TREATMENT.

Same as in similar cases; after six hours rest felt better; pulse 76 per minute and stronger; is sent home.

April 17.—Felt well, but weak; pulse 78 per minute; parapsis of both legs disappeared.

April 18th.—Still stronger; pulse 80 per minute. After examination finding him unfit to return to work in the air-chambers, he was forbidden to go in any more.

CASE XXIV.—APRIL 18TH.

West Pier. Barometer 29° 70′. Thermometer 58°. Weather clear. Pressure 40 pounds to the square inch.

AUGUST NIEDERMEYER, 20 years; nativity, Germany; was taken sick after the second watch of two hours which he had worked in the caissons; went to work with a friend, and, notwithstanding the orders, was not examined before; was taken sick immediately after coming up, and brought to the hospital in an insensible condition; patient of medium stature, but very slenderly built.

SYMPTOMS.

Face livid, pulse 110 per minute, and paresis of both legs.

TREATMENT.

Same as before followed for one hour, after which the pulse was 94 per minute; continued the same for three hours longer, when the pulse was 89; kept him all night at the floating hospital, and on the following (19th) at 7 o'clock A.M., pulse 84 per minute; the paresis had subsided, but he felt weak; sent him home, with injunction not to return in the air-chambers; but notwithstanding which, he did, two days after, and was retaken with the same symptoms

after the first watch. The same treatment was followed, and he recovered, but was for a month very feeble.

CASE XXV.—April 18th.

West Pier. Barometer 29° 70′. Thermometer 58°. Weather clear. Pressure 40 pounds to the square inch.

James W. Galloway (foreman), 29 years; nativity, United States; worked two months and twenty days; had suffered before of pains in both legs, but after a day's rest returned to work. This time he was taken sick after the last watch, about half an hour after coming up, and immediately after reaching home. The patient is of medium stature, and well built.

SYMPTOMS.

Complained of violent epigastric pain, and as soon as taken sick, paraplegia also had supervened; pulse 64 per minute; he had not urinated for six hours, and retention of urine existed—the bladder being very much distended. Catheterism was used, and drew three pints of highly-colored but clear urine.

TREATMENT.

Same as in similar cases.

April 19th, 8 A.M.—Found the patient restless; pulse 85 per minute; had been obliged to use the catheter himself during the night; suffering from great distension of the bladder, from which he drew the same quantity of urine as before; the paraplegia still existed, and the catheterism was used every eight hours.

April 20th.—Pulse 90 per minute; had been restless until he had two involuntary stools in the night, but did not urinate, and the bladder being full, he had to catheterise himself. There being no prospect of immediate improvement in his case, the patient desired to be removed to St. Luke's Hospital, to remain under my care.

April 21st—Patient removed to the hospital, and is better; pulse 85 per minute; paraplegia has partially subsided; was able to move his legs a little, but still obliged to use the catheter every eight hours —the bladder, when distended, causing such pain that it was impossible for him to endure it any longer.

April 22d.—Same.

April 23d and 24th.—Same.

April 25th.—Better; pulse 80 per minute; appetite good; slept well, but obliged to catheterise himself every six hours.

April 26th, 27th, and 28th.—Same.

April 29th.—Had a chill last night, which was followed by strong fever, and ceased only in the morning; pulse 92 per minute and full; tongue very coated and dry; towards evening, when he catheterised himself, some pus was detected in the urine.

April 30th.—Same; pulse 95 per minute; more pus in the urine, which was very fœtide, and became ammoniacal very quick.

May 1st.—From this day the patient showed similar symptoms, and his case took the same course as case VII. The same treatment was then followed until the 31st of the same month, at which time he had nearly recovered; his pulse was 80 per minute, his appetite good, slept well, urinated freely, bowels regular, and he commenced to gain flesh; contemplated returning to his home in Indiana in a few days. From the 1st June to the 8th, he took gradual out-door exercise every day.

June 9th and 10th.—Feeling well and strong; on the 11th left for home, recovered.

July 30th.—Had news from him, when he was in good health and strong.

CASE XXVI.—APRIL 19TH.

West pier. Barometer 29° 65′. Thermometer 62°. Weather cloudy. Pressure 40 pounds to the square inch.

MIKE MCCOOLE, 29 years; nativity, Ireland; had worked three weeks; was taken sick after the first watch, commencing at 5 o'clock A.M. and ending at 7 o'clock A.M.; had not taken any breakfast before going to work; was taken sick immediately after coming up, and was in a syncopal condition when brought to the hospital. Of small stature, but well built.

SYMPTOMS.

Face very pale; pulse 110 per minute and feeble; parapsis had supervened when brought to the hospital.

TREATMENT.

The treatment followed was the same as in similar cases, and one hour after his pulse was 90 per minute, and stronger. Continued the same treatment for two hours longer, after which his pulse was 85 per minute, and the parapsis had disappeared. Kept him at the floating hospital until evening, when his pulse was 82 per minute and good, and he felt well enough to go home, intending to rest a few days.

April 21st.—Felt well, and expected to return to work, if allowed.

CASE XXVII.—APRIL 19TH.

West pier. Barometer 29° 65′. Thermometer 62°. Weather cloudy. Pressure 40 pounds to the square inch.

P. JOHNSON, 24 years; nativity, United States; had worked one week; was taken sick after the last watch, immediately after coming up. He is tall, and slenderly built.

SYMPTOMS.

Face livid, and covered with profuse perspiration; pulse 110 per minute and feeble; complained of epigastric pain, and had a syncope when brought to the hospital.

TREATMENT.

Same was followed as in similar cases for one hour, after which the pulse was 94 per minute; same treatment continued for two hours longer, when the patient felt much better, pulse being 85, and stronger; still feeling very weak; kept him all night at the floating hospital, and the following morning, April 20th, he felt much better; pulse 82 per minute; slept well, and was well enough to go home by himself.

CASE XXVIII.—APRIL 22D.

West Pier. Barometer 29° 65′. Thermometer 77°. Weather clear. Pressure 40 pounds to the square inch.

ALFREN KOENER, 19 years; nativity, Germany; has worked three weeks; taken sick after the last watch, and immediately after coming up; of tall and slender build. This case was similar to case XXVII., and *the treatment followed* was the same. After eight hours rest he was able to go home by himself.

CASE XXIX.—APRIL 24TH.

West Pier. Barometer 29° 65′. Thermometer 72°. Weather cloudy. Pressure 40 pounds to the square inch.

PATRICK FEELAN, 22 years; nativity, Ireland; worked two weeks in the air-chambers; was taken sick after the last watch, immediately after coming up; of medium stature, slenderly built. This case was similar to case XXVII. *The same treatment* was followed with the same result. He was kept at the floating hospital all night, and went home well the following morning.

CASE XXX.—APRIL 25TH.

West Pier. Barometer 29° 88′. Thermometer 67°. Weather cloudy. Pressure 40 pounds to the square inch.

ROBERT ALLEN, 29 years; nativity, Ireland; worked three weeks; was taken sick after the last watch, about

twenty minutes after coming up; patient of medium stature, and well built.

SYMPTOMS.

Face was livid and covered with profuse perspiration; pulse 64 per minute; complained of violent epigastric pain, and paresis had supervened in both legs.

THE TREATMENT

Used in similar cases was followed for one hour, when the pulse was 70 per minute, and after two hours longer was 74 per minute; kept him all night at the floating hospital, and saw him on the following morning, April 26th, at 8 o'clock A.M., when his pulse was 76 per minute, and the paresis had ceased; feels well, but weak; desired to go home, and left accordingly.

CASE XXXI.—APRIL 25TH.

West Pier. Barometer 29° 88′. Thermometer 67°. Weather cloudy. Pressure 40 pounds to the square inch.

ANTONY PATOCHY, 32 years; nativity, Germany; worked nine days; was taken sick after the last watch, immediately after coming up; tall, and of slender build. This case was similar to case XXVII. *The treatment followed* was also the same, and eight hours after, he was able to go home without assistance.

CASE XXXII.—APRIL 25TH.

West Pier. Barometer 29° 88′. Thermometer 67°. Weather cloudy. Pressure 40 pounds to the square inch.

JOHN KEARNEY, 24 years; nativity, Ireland; had worked two months and twenty days; was taken sick after the last watch, half an hour after coming up, and immediately after reaching home; above medium stature, and well built. His case was similar to case XXVII. *The treatment* was the same. He recovered and was well enough to recommence work after a week.

CASE XXXIII.—April 28th.

West pier. Barometer 29° 67′. Thermometer 54°. Weather cloudy. Pressure thirty-eight pounds to the square inch.

Peter Peterson, twenty-four years; nativity, United States; worked four months; was taken sick after the last watch, and immediately after coming up; of medium stature and well built.

This case was similar to case XXII, and was treated accordingly. After eight hours rest he was permitted to go home.

CASE XXXIV.—April 28th.

West Pier. Barometer 29° 67′. Thermometer 54°. Weather cloudy. Pressure thirty-six pounds to the square inch.

——— Arcom, twenty-one years; nativity, Germany; worked two and one half months; was taken sick after the last watch, and immediately after coming up; of medium stature and well built.

This case was similar to case XXVII., rather more severe; treatment similar; was kept all night at the floating hospital, and on the following morning was able to go home.

On the twenty-third of April it was found that the air-pumps forcing the compressed air into the air-chambers, instead of being cold were becoming heated for want of a sufficient supply of cold water in the boxes attached to them. During two days, the temperature in the air-chambers, which previously averaged fifty (50) degrees, increased to sixty (60), and on the 25th rose to sixty-eight (68), but by keeping the air-pumps cool the temperature did not exceed sixty-six (66) degrees. The compressed air, after passing through the equalising valve from the air-chambers into the air-lock, increased its temperature by the

friction through it. The consequence was that the *temperature in the air-lock increased from 15 to 18 degrees above the temperature in the air-chambers*, while the working men were in the air-lock and passing from the normal atmosphere into the air-chambers. Another cause of the still further increase of the temperature was the heat produced by the *temporary stay of the workmen* (*ten in number*) *in so small a space as was the air-lock, it having only one hundred and sixty-two* (162) *cubic feet capacity for all* (*ten men being the average number*) *going into it at the same time, allowing only a very small fraction over sixteen* (16) *cubic feet for each man.* This explains why the temperature increased so much during their stay in the air-lock whilst going to work in the air-chambers.

In order to prevent further increase of the temperature in the air-lock, it was directed that a wooden box be made to fit closely the side of the wall of the air-lock in the air-chamber, and where the opening of the equalizing valve into the air-lock was situated, the box to contain fifty pounds of ice broken into pieces the size of a man's fist; the side of the box opposite the one next to the wall of the air-lock, bored with about thirty holes of one-eight of an inch in diameter, through which the greatest part of the compressed air, before escaping through the equalizing valve had to pass, as also through the ice in the box, *which was to be kept constantly full while the men were working in the air-chambers.* The compressed air, consequently, being cooled before entering the air-lock, prevented the temperature increasing above 68° while the men were in the air-lock or going to work in the air-chambers, thus avoiding, as far as possible, the pathological effects which certainly would have been caused by the high temperature and increased atmospheric pressure of thirty-five (35) pounds to the square inch.

So far, we had obtained some success by the prophylactic means used, as also by the treatment followed in the numerous cases which occurred, since we commenced our professional attendance at the bridge. Still we were not satisfied with the results obtained. From repeated observations, believing that exhaustion caused by an excess of waste on the bodies of those working in the air-chambers—waste, which, going on by their repeated exposure in an over-condensed atmosphere was one of the principal causes of the frequency of cases. In order to ascertain this, we thought, that if there was an extra waste on the system of the men working in the air-chambers it would manifest itself under the form and by an excess of urea, to be eliminated by the kidneys during the secretions of urine, besides the quantity of urea not accounted for and contained in the profuse perspiration with which the men were constantly covered when working in the air-chambers.

We then proceeded to make examination of the urine of healthy men who had worked, and were still working, in the air-chambers, with the following results :

The examinations were made on the urine of thirty-two men on the 28th and 30th of April, and *immediately after the men came out of the air-chambers, and before they had taken their dinner, or any food or spirituous drink for at least seven hours, and had urinated at least twice during that time.*

The examinations were also made on the urine of four sick men, drawn at the second time the catheter was used, and about eighteen hours after they were taken sick.

No.	Names.	Age.	Had worked in the air-chambers.	Spec. Gra'y	Chemical Reaction.	Remarks.
1	R. Colgan	38	3 months	1025	Neutral.	
2	Mike McCoole	24	3 weeks	1029	"	Taken sick case 26.
3	George Hetzel....	25	3 mths 1 week..	1023	"	
4	Thomas Morris...	28	3 mths 1 week..	1028	"	Taken sick case 39.
5	John Dering	23	3 mths 1 week..	1023	"	Taken sick case 47.
6	Stenson	25	15 days	1018	"	
7	W. Dudley.....	17	7½ weeks	1028	"	Taken sick case 37.
8	Thomas Connelly.	39	5 months	1026	"	
9	William Welsh....	24	3 months	1028	Alkaline.	Taken sick case 43.
10	August Donkey...	36	3 months	1027	Neutral.	
11	August Meyer....	30	5 months	1026	"	
12	James Cham.....	45	5 months	1025	Alkaline.	
13	T. R. Taffey.....	25	3 months	1023	Neutral.	
14	Walter Sawer.....	20	5 months	1030	"	
15	John Conroy.....	23	1 month	1025	"	
16	Patrick Ford	22	5 months	1025	"	
17	O'Keeffe, Foreman	26	4½ months	1020	"	
18	M. McDermot.....	25	3½ months	1020	"	
19	A. Wimer	30	2 months	1020	"	
20	W. Hogan.....	42	3 months	1022	"	
21	T. Kelsey.....	36	5 weeks	1032	"	Taken sick case 9.
22	Donelly	32	4½ months	1029	"	Taken sick case 36.
23	G. Clency	20	2 months	1028	"	
24	W. Burns	19	3 months	1026	"	
25	Ed. Green.....	35	1½ months	1030	"	Taken sick case 42.
26	L. G. Thompson..	29	4 months	1027	"	
27	Mike Herwin	24	3 months	1029	"	Taken sick case 40.
28	Loomis	27	4½ months	1033	"	
29	Tucker	40	4½ months	1033	"	
30	Brown, Foreman..	44	4½ months	1030	"	
31	G. Murphy.....	17	3 months	1030	"	
32	P. Reynolds.....	24	1½ months	1025	"	

The urine of the four sick men was as follows:

33	Ansep Miller	20	7 weeks	1036	Neutral.	Case 12.
34	Lyons, Foreman,	30	4½ months	1035	"	Case 2.
35	J. W. Galloway..	29	2 mths 3 weeks	1035	"	Case 15.
36	Louis Boyer.....	24	6 hours.....	1030	Alkaline.	Case 7.

By the above statement it will be seen that, excepting

six, the quantity of urea found was greater than in healthy urine of men working in the open air, and which specific gravity is from 1010 to 1020, whereas among the cases above enumerated, the specific gravity of urine was over 1023, notwithstanding its dilution, as the men were drinking water freely, and among those taken sick the quantity of urine, so far from being less, had increased.

Notwithstanding all the vigilance and care taken to prevent the recurrence of cases, no satisfactory results were obtained until the following rules were strictly enforced:

1st. The time of work was reduced to two watches, instead of three; and as the work of filling up the air-chambers progressed—the space becoming smaller—the number of workmen was gradually decreased, and the time of work in each watch was reduced to one hour, instead of two, and with three hours rest between each.

2d. The men were not allowed to go ashore from the time they commenced their day's work. They had also to take their dinner with them, to prevent any excuse for leaving the piers; and if a man absented himself, even for one day, he had to be re-examined by the physician before returning into the air-chambers.

3d. The men, when coming up from work, were compelled to remain quiet, or lie down, for at least half an hour; and when taking their dinner, by my direction, each man was provided with three quarters of a pint of beef tea, which was made with Liebig's extract of meat, in the proportion of six ounces of extract to a gallon of boiling water. The same was also subsequently given to the men working in the air-chambers at the east pier, after they recommenced work.

These rules were enforced from the 28th April until the 8th May, when the filling up of the air chambers at the west pier caisson was completed, and no more cases happened during the last ten days.

After the filling up of the air-chambers at the west pier was completed, the men were allowed a few days rest, until they should recommence the same work, which had been interrupted at the east pier by the breaking of the coffer-dam over the caisson.

The work of filling up the air-chambers with concrete was recommenced at the east pier on the 11th May.

The duration of time of work was directed to be three hours per day, divided into three watches of one hour each, with three hours rest between each watch.

Notwithstanding all the care taken, we must say that on the first day the work recommenced—*it being impossible then to enforce the rules which had been adopted for the west pier*—some of the men came without their dinner; and among those who commenced to work that day one fatal case occurred, but which really ought not to be taken into account among the number of cases, it being the result of the imprudence on the part of the sufferer, and which is case XXXV.

CASE XXXV.—MAY 11TH.

East Pier. Barometer 29° 68′. Thermometer 66°. Weather cloudy. Pressure 49 pounds to the square inch.

WILLIAM SAYLER, 30 years; nativity, Germany; of medium stature, and well built; worked three months in the west pier, where the pressure was for two weeks 40 pounds to the square inch, from which he suffered no inconvenience.

He worked from 8 to 9 o'clock A. M. and felt well after coming up. He had not brought his dinner with him, and at half past 11 he went ashore, he said, to take his dinner, which he did not do, but drank without eating anything, as will be proved hereafter. He returned shortly before 1 o'clock, P. M., his watch being from 1 to 2 o'clock, and resumed work.

After his watch was over, and immediately after leaving the air-lock, and while ascending the stairs in the shaft, he was taken sick, had to be carried up, and became insensible while being carried to the hospital, where I saw him a few minutes after. He remained insensible until 4.20 P. M., when he died.

Post mortem examination was held sixteen hours after death, and which elicited the following facts:

Cranium. All the blood vessels of the scalp, as also all the membranes covering the brain, were highly congested, and about two ounces of serum escaped from the vertebral canal when the brain was removed. The brain was congested and two ounces of serum found in the ventricles.

The Heart was of normal size; the right ventricle, as also the left, were normal. The lungs were inflated and of normal appearance, but there were large adherences around the base of the right, and which seemed to be of long standing. The liver was normal as well as the spleen. The kidneys were normal, as was also the bladder, but empty. The stomach normal *and entirely empty; no traces of food were found*, which confirmed my opinion that this man had not taken any dinner, and probably a very light breakfast, but had been drinking quite freely, as it was afterwards ascertained.

We must say, moreover, that the gang with which this man had been working in the air-chambers, after quitting work, and while in the air-lock on their return into the normal atmosphere, allowed the compressed air to escape too freely, *so that the equalization of pressure with the open air took place too rapidly*, and by remaining less than four (4) minutes in the air-lock, whereas the time necessary for *the gradual equalizing of pressure with the normal atmosphere* ought to have been eight and one half ($8\frac{1}{2}$) minutes.

On the 12th of May, the same regulations adopted at the West pier were enforced, and it will be seen, that notwithstanding the increase of pressure to which the men were exposed in the air-chambers, the number of cases was not only greatly diminished, but they were of a less serious character.

CASE XXXVI.—May 12th.

East Pier. Barometer 29° 70′. Thermometer 62°. Weather cloudy. Pressure 40 pounds to the square inch.

Donelly, (foremen,) 32 years; nativity, Ireland, had worked four months; had suffered from epigastric pains before, but recovered after a few days rest, and then returned to work. At this date he was taken sick after the second watch.

His case was similar to XXVII. The *same treatment* was followed; he recovered, but was forbidden to return to the air-chambers, and was given work elsewhere.

CASE XXXVII.—May 12th.

East Pier. Barometer 29° 70′. Thermometer 62°. Weather cloudy. Pressure 49 pounds to the square inch.

W. Dudley, 17 years; nativity, United States; tall and slender build; worked two months and a half; taken sick after the second watch, immediately after coming up. This case was similar to case XXVII. but less severe. *The same treatment* was followed, and after eight hours rest, he was able to return home.

CASE XXXVIII.—May 12th.

East Pier. Barometer 29° 70′. Thermometer 62°. Weather cloudy. Pressure 49 pounds to the square inch.

James Jennings, 30 years; nativity, United States; of medium stature, and well built; worked two months; taken sick after the second watch. This case was

similar to case XXVII., but less serious. *The same treatment* was followed, and after six hours he went home.

CASE XXXIX.—May 12th.

East pier. Barometer 29° 70′. Thermometer 62°. Weather cloudy. Pressure 49 pounds to the square inch.

Thomas Morris, 28 years; nativity, Ireland; of medium stature, and well built; worked three months and three weeks; taken sick after the second watch, about twenty minutes after coming up. This case was similar to case XXX., but less serious. *The same treatment* was followed, and after twelve hours rest he was able to go home.

CASE XL.—May 14th.

East Pier. Barometer 29° 80′. Thermometer 70°. Weather clear. Pressure 50 pounds to the square inch.

Michael Herwin, 24 years; nativity, Ireland; of medium size, and well built; has worked three months and a half; was taken sick after the last watch, half an hour after coming up, and immediately on reaching home; saw him half an hour after, and observed a difference in the symptoms from other cases.

SYMPTOMS.

The face was flushed; pupils contracted; the skin hot; pulse 110 per minute, but moderate. The patient complained of parapsis of both legs, and of shooting pains in the chest. A few minutes before I came, he had spat some blood, and did the same during my visit. The blood was very red, and the total quantity was about three ounces. The auscultation revealed crepitation at the anterior and middle part of the right lung. The tongue was slightly coated, and he had had no evacuation from the bowels for two days.

TREATMENT.

I prescribed one enema with two fluid drachms of tincture of assafœtida and two pints of tepid water, which, after administration, produced two large evacuations; he afterwards slept a little.

May 15th, 8 o'clock A.M.—Pulse 90 per minute and soft; feeling much better; the parapsis of both legs had subsided; had spitted blood twice in the night; he asked to be removed to the St. Luke's Hospital, to remain under my care.

May 16th.—Removed to the hospital; had some fever last night, but is better this morning, and spits no more blood.

May 17th.—Same; pulse 88 per minute; skin moist.

May 18th.—Same.

May 19th.—Commenced to cough and expectorate; the sputum is semi-purulent, with a slight tinge of blood; pulse 86 per minute; the auscultation reveals the same crepitation on the right lung; felt better, with some appetite.

May 20th, 21st, 22d.—Same; pulse 82 per minute; skin good; bowels regular; expectoration continues, but without blood.

May 23d, 24th, 25th.—Same.

May 26th, 27th.—The expectoration ceased; very little crepitation existed in the right lung; pulse 82 per minute; felt well, and left the hospital on the following day.

CASE XLI.—MAY 15TH.

East pier. Barometer 29° 78′. Thermometer 80°. Weather clear. Pressure 48 pounds to the square inch.

JOHN WOOD, 24 years; nativity, England; of medium stature and well built; worked two and one half months. This case was similar to case XXVII, but less severe. *The treatment* followed was the same, and after six hours rest went home.

CASE XLII.—May 15th.

East Pier. Barometer 29° 78′. Thermometer 80°. Weather clear. Pressure 48 pounds to the square inch.

Edward Green, 35 years; nativity, Ireland; tall and slenderly built; worked two months; had previously suffered with parapsis of both legs, from which he recovered; and, after a few days' rest, returned to work. This time he was taken sick after the second watch, and immediately after coming up. This case was similar to case XXVII. *The treatment* was also the same, and after eight hours rest he went home. In a few days he returned to work; was retaken with the same symptoms after the second watch. The same treatment was again resorted to; he recovered a second time, but before returning home he was discharged from further work in the air-chambers.

CASE XLIII.—May 16th.

East Pier. Barometer 29° 75′. Thermometer 83°. Weather clear. Pressure 47 pounds to the square inch.

William Welsh, 21 years; nativity, Ireland; above medium height and well built; worked four months; was taken sick after the last watch, about twenty-five minutes after coming up, and while on board the boat crossing the river to the shore. He was taken home, where I saw him a few minutes after. This case was similar to case XXX but less severe. *The same treatment* was followed, and on the following morning he was much better, but very weak. He was advised not to return to the same work.

CASE XLIV.—May 16th.

East Pier. Barometer 29° 75′. Thermometer 82°. Weather clear. Pressure 47 pounds to the square inch.

John Murray, 19 years; nativity, United States; above medium stature and well built; worked four months; was taken sick after the last watch. Similar to case XXVII. *The same treatment* was pursued, and on the following morning he was well, but quite weak.

CASE XLV.—MAY 15TH.

East Pier. Barometer 29° 75′. Thermometer 82°. Weather clear. Pressure 47 pounds to the square inch.

M. O'KEEFE, 35 years; nativity, Ireland; medium stature and well built; has worked four and one half months; taken sick after the last watch, and about twenty minutes after coming up. This case was similar to case XXX but less severe. *The treatment followed* was the same; he recovered, but was weak for five or six days.

CASE XLVI.—MAY 16TH.

East Pier. Barometer 29° 79′. Thermometer 82°. Weather clear. Pressure 47 pounds to the square inch.

STEPHENS HENRY, 22 years; nativity, United States; medium size, and well built; worked four months; was taken sick after the second watch. This case was similar to case XXX, but less severe. *The same treatment* was followed, and after eight hours rest the patient was allowed to return home.

CASE XLVII.—MAY 21ST.

East Pier. Barometer 29° 80′. Thermometer 48°. Weather clear. Pressure 47 pounds to the square inch.

STEVEN DERING, 23 years; nativity, Ireland; above medium stature, and well built; worked four months and a half; was taken sick after the second watch, 11 o'clock A.M. This case was similar to case XXX, but less severe. *The same treatment* was followed, and after remaining in the floating hospital until the next morning, he was better, but weak, and went home.

CASE XLVIII.—MAY 22D.

East Pier. Barometer 29° 74′. Thermometer 80°. Weather clear. Pressure 47 pounds to the square inch.

JAMES HOWARD, 23 years; nativity, United States; medium height, and well built; worked one month and a half; taken sick after the second watch at 12

o'clock, M. This case was similar to case XXX, but less severe. *The same treatment* was followed, and on the following day he was much better, but weak.

CASE XLIX.—MAY 27TH.

East Pier. Barometer 29° 70′. Thermometer 75°. Weather clear. Pressure 45 pounds to the square inch.

H. G. HARVEY, 19 years; nativity, England; air-lock-tender; of small stature, but square built; had worked six months; taken sick once before, on the 28th February, and suffered then of parapsis, which subsided the following day, and he returned to work after four days' rest. This time he was taken sick after the second watch, at 10 o'clock A.M. This case was similar to case XXX, but less severe; and after the treatment followed in similar cases, and eight hours rest, he was well enough to go home.

Besides these forty-nine cases we had under our care at the east and west piers, *there will be found twenty-eight other cases in Chapter XII.*, which occurred during the sinking of the east abutment caisson, and to which we will refer hereafter—*these cases, for the present, not properly belonging to the subject we now have under consideration.*

CHAPTER VIII.

PROGRESS OF THE WORK AFTER RECOMMENCING AT THE EAST PIER—CHANGE OF THE ATMOSPHERIC CONDITION IN THE AIR-LOCK AND AIR-CHAMBERS DURING THE FILLING UP WITH CONCRETE—CONSIDERABLE INCREASE OF TEMPERATURE IN THE AIR-LOCK.

After having experienced the successive increase of temperature in the air-chambers, as also a more considerable increase in the air-lock, at the West pier, it was supposed that at the East pier, where the pressure was higher, the temperature would certainly increase in proportion.

It was then deemed necessary to have the air forced into the air-chambers by the force pumps, to pass through several large coils of red copper pipes, the coils five feet in diameter, and the pipes of the same diameter as those of the air-pumps, the said coils equal in length to 150 feet of pipes, and to be submerged in the river, the temperature of which being lower than the atmosphere would cool the air before its entrance into the air-chambers.

This was accordingly done, *but the coils not being ready before the 12th of May, at noon*, the increase of temperature in the air-chambers, we think, caused four cases to occur in the middle of the day, as will be seen by the cases XXXVI, XXXVII, XXXVIII and XXXIX. As soon as the compressed air passed through the coils of pipes submerged in the river before entering the air-chambers, then the temperature ceased to increase above 66° in the air-chambers. After a few days the space in the air-chambers becoming smaller, by the filling up with concrete, the temperature increased again

by the constant mixing up of the hydraulic cement with water, used to make the concrete, as, for illustration, the slackening of fresh lime will do. Then the temperature increased, notwithstanding all the care taken to prevent it, and during the remainder of the work ranged from 66° to 72° in the air-chambers, as the statement hereafter will exhibit.

But in the air-lock the temperature was considerably more every time the men had to go from the normal atmosphere through the air-lock into the air-chambers. So much so, that on the 12th May, at 11 o'clock, A. M., the thermometer indicated 92°, and this at a pressure of 49 pounds to the square inch. An ice box, like the one used at the West pier in the air-chambers, and in front of the equalizing valve with the air-lock, was made, and used immediately in the air-chambers, and continued until near the completion of the work, and with the following results:

We give herein a statement of the temperature in the open air, in the air-chambers, and in the air-lock, when going from the normal atmosphere into the air-chambers, and since the 12th May, 4 o'clock P. M., until the 27th, at noon, the day of the completion of the filling up of the air-chambers at the East pier.

OBSERVATIONS OF THE TEMPERATURE AT THE EAST PIER

DURING THE LAST TWO WEEKS' WORK.

DATE.	TIME.	TEMPERATURE.			STATE OF ICE-BOX.	Pressure.
		Open-air.	Air-chambers.	Air-lock on entering Air-chambers.		
May 12	4 p.m.	66°	66°	82°	Full.	49 lbs.
" 13	2 "	82	66	82	"	49 "
" 14	2 "	77	68	82	"	49 "
" 15	2 "	78	70	80	"	48 "
" 16	12 m.	82	64	74	"	47 "
" 17	12 "	84	70	90	Empty but refilled immediately	47 "
" 18	12 "	86	72	92	"	47 "
" 19	2 p.m.	84	72	80	Full.	47 "
" 20	1 "	86	69	80	"	47 "
" 21	12 m.	85	68	89	Empty but refilled immediately	47 "
" 21	5 p.m.	91	69	81	Full.	47 "
" 22	12 m.	80	68	80	"	46 "
" 23	1 p.m.	80	68	80	"	46 "
" 24	12 m.	77	67	80	"	46 "
" 25	12 "	78	69	86	None used.	45 "
" 26	12 "	78	70	88	"	45 "
" 27	12 "	75	70	89	"	45 "

During the last three days the temperature was higher in the air-lock, *the ice box being taken away, there being no room for it*; but the successive, constant, and alternative opening of both air-lock doors partially supplied the difference for lowering the temperature, the room in the air-chambers becoming so small that *three or four men only were allowed to work at a time*, and not more than half an hour each time, until the filling up of the air-chambers was completed.

CHAPTER IX.

FREQUENT EXAMINATIONS, DURING THE TIME OF WORK, OF THE MEN WORKING IN THE AIR-CHAMBERS—AN ALMOST CESSATION OF CASES.

The results obtained so far, since my attendance at the bridge, if not entirely successful, had at least been encouraging, and not to leave anything undone which could be done to prevent the effects of compressed air on the men working in the air-chambers.

As has been shown in the tabular statement, chapter VIII., from the 12th May the temperature in the air-chambers being so much above the temperature which existed before; the pressure being 48 pounds to the square inch, and the work progressing day and night, the condition of the atmosphere in which the men had to work, being changed by the increase of temperature, suggested to me, the possibility of the appearance of other symptoms, which had not been observed before among the working men. Having always examined the time taken by a gang of workmen when coming through the air-lock to return into the normal atmosphere, and that, notwithstanding my directions and positive orders, not to come out too quickly, *sometimes they took too short a time to do it*—that is to say, if the pressure was 45 pounds to the square inch, instead of remaining from seven to eight minutes in the air-lock, to equalise the pressure with the open air in the shaft, they remained only from three to four minutes at the longest.

To prevent a further recurrence of this, I directed that the equalizing valve between the air-lock and the open atmosphere should be altered,—that is to say, I had the area of the opening of said valve reduced, which change had the desired result.

Since the recommencing of the work at the east pier, besides the cases which are recorded in chapter VII., some of the men working in the air-chambers, a few minutes after coming up, complained of the excessive heat in the air-lock and air-chambers, and also of being very tired; many of them complained of headache, principally on the frontal and temporal regions. Their pulse was not over 90 per minute, but feeble; the light had more than its usual effect on their pupils, which were in the majority of cases abnormally contracted, those symptoms indicating, to a certain extent, a disposition to a certain form of meningitis.

We then considered necessary from the 14th of May *to examine the men more frequently, to prevent, if possible, an increase of those symptoms.* From that day we examined every man, after coming up from the air-chambers, regularly every six hours, day and night; and as soon as any one of them complained, we made him rest one watch. In the most of cases all the symptoms disappeared, but in some they returned, then we considered prudent to prevent such ones from returning to the same work. *We believe that by systematic examinations* of the men every six hours, when the work progressed, as also by the strict enforcement of the rules already referred to, we obtained, as near as possible for the present, all the results looked for; and we are able to say that from the 12th of May until the 27th, the day of the completion of the work in the air-chambers, at the east pier, there were no more fatal cases; and if there were any others, they were less severe, every one of them recovering rapidly, enabling the patient to return to work within a few days.

CHAPTER X.

ANALYSIS OF THE PATHOLOGICAL EFFECTS AND OF THEIR CAUSES—EFFECTS OF COMPRESSED AIR ON MAN AS A LABORER IN THE AIR-CHAMBERS, AND ON MAN AS A CASUAL VISITOR.

As we have seen, by observation of forty-nine cases in chapter VII., the similarity of symptoms, varying only in their intensity, the same treatment followed for all, and the ultimate recovery of forty-five of them, oblige us to differ as to the cause or causes which produced such pathological effects; and leads us not only to suppose, but to affirm, that exhaustion of the system under certain circumstances has been, with a very few exceptions, the cause of what have been called "bridge cases."

In support of our views on this theory of exhaustion, as some may call it, we have to examine, first, the function of respiration. It is an admitted fact that oxygen in excess in the normal atmosphere, has the effect to increase the force and activity of the pulse, and that the same atmosphere in which the excess of oxygen exists, may be still respirable and support life; provided, the proportion of oxygen will *not exceed ten per cent.* above the normal quantity already existing in it; and that if a person is obliged to remain for a certain length of time in an ambient atmosphere where oxygen is in the proportion of *ten per cent. in excess*, we observe that the respiration is increased in frequency.

It is admitted that the increase of respiration, or circulation, produces an excess of waste on the system, which, if long continued, *exhausts it.*

If then, such is the case, when a person is exposed only to a surrounding atmosphere which contains no more than ten per cent. in excess of oxygen above the quantity in the normal atmosphere, what will be the result on a man who is obliged to use great muscular exertions, and *to work in an ambient atmosphere containing from three hundred and thirty five to four hundred per cent. more oxygen* than in the normal?

Let us, then, examine the condition in which the men working in the air-chambers were placed.

The number of respirations for an adult in the normal atmosphere, average eighteen per minute. The average quantity of air introduced into the lungs of a medium-sized healthy man, at each inspiration, is 115 cubic inches, when breathing; which gives for eighteen inspirations per minute, 2076 cubic inches of air, and represents 477 48–100 cubic inches of oxygen. But, if we now take into consideration the pressure under which the men had to work in the air-chambers, *which pressure has been as high as fifty* (50) *pounds to the square inch, but which we will only take at forty-five* (*45*) *pounds to the square inch*, as a base for our calculation, we will demonstrate the enormous difference in the proportion of air which is inspirated into the lungs of the working-men or visitors remaining in the air-chambers for a certain length of time.

The pressure being forty-five (45) pounds to the square inch, as we have said, instead of eighteen inspirations per minute, *they are increased to 21, and, instead of 2076 cubic inches inspirated per minute there are 2415, representing* 555^{45} *cubic inches of oxygen* instead of 477^{48}. But now, if we have to multiply this result by four (4), being the number of atmospheres which was the pressure in the air-chambers, *then it will give* 9660 *cubic inches per minute, and the proportion of oxygen will be* 2221^{80} *cubic inches coming in contact* with the

respiratory surface or wall of air-cells of the lungs *every minute, instead of* 477^{48} when breathing in the normal atmosphere.

Notwithstanding the normal proportion in which the oxygen exists with the other constituents of the normal atmosphere, nevertheless, that same atmosphere being *condensed until the pressure is forty-five* (45) *pounds to the square inch, the quantity of oxygen which we said, was inspirated per minute* instead of the quantity existing in the normal atmosphere.

It has been said "*that the proportion of oxygen which the red corpuscles of the blood are capable of containing are, to a certain degree, absolute, and do not depend upon physical conditions, such as pressure.*"

This is true when the oxygen is in excess of its proportional constituent in the normal atmosphere; but the function of respiration of the men working in the air-chambers is taking place in an over condensed atmosphere, and not only the same number of cubic inches of surrounding compressed air in which they are is inspirated by them, but even more, the number of respirations being twenty-one (21) per minute, instead of eighteen (18) in the normal atmosphere.

We believe that exposure over a certain length of time to such an atmospheric pressure, is more than sufficient to cause abnormal, if not pathological, effects upon the men employed in the air-chambers.

Now, if we consider the excess of waste on the system which is going on, and ought to be proportional to the time that the men have to remain in the air-chambers; each time, being two hours duration, three times a day, with an interval for rest of two hours only between each time of work, we have the following results:

A healthy man breathes, when in the air-chambers during two hours, *at the rate of* 2221^{80} *cubic inches of oxygen per minute, instead of* 477^{48} *in the normal atmosphere; the waste on his system will certainly be more in*

proportion than in the normal atmosphere, this proportional waste being caused by the inspiration of compressed air which contains no more oxygen than in the proportion of the constituents of the normal atmosphere, but so much more in considering the proportion of the pressure existing in the air-chambers, as we have shown above.

Suppose, for instance, that a man can stand this change the first time he has been exposed to such atmospheric pressure, and comes out of the air-chambers feeling as well as when he went in, there is no doubt that, notwithstanding his feeling well, the waste on his system was going on, as we said. How long will it take for that man to repair the waste made on his organism by his sojourn of two hours in an atmosphere at the pressure of forty-five (45) pounds to the square inch? From facts observed, we answer: for that man, besides the time of rest allowed to men working in the normal atmosphere, it will take a very small fraction less than three hours and a half to recover only from the increased waste by exposure in such a condensed atmosphere—*waste which has been going on at a quadruple rate* compared with the waste on a man working in the normal atmosphere.

But, now, if, instead of a healthy man who has been exposed for two hours in a condensed atmosphere, it is a man whose health has been more or less impaired by irregular habits or sickness, *will it be safe for that man to expose himself to the effects of the waste constantly going on on his system*, if he is obliged to return to work after two hours rest only, and this repeated three times during the day? *We think not.*

The change on the healthy man, we may say more properly, the loss of vitality or force of resistance caused by the waste on his system, already impaired by returning too soon to work in the air-chambers, *that is to say after two hours of rest only*, and when he had not yet

recovered from this waste, and returning to work once, and even twice, on the same day in the same condensed atmosphere, *and at each time more exhausted by work and exposure* than when he commenced in the morning. The chances for that man are, if he persist in his work, and expose himself to the continual exhaustive power of the condensed atmosphere, he certainly will be affected by it, and present the same pathological symptoms that we have observed on the forty-nine cases that we had under our care; and far more serious will be the effects on the man of impaired health or delicate constitution.

There is no doubt that on the men working in the air-chambers the waste on the system was increased in proportion to the pressure existing in the air-chambers. Have we not found on examination an excess of urea in the urine of healthy men who had worked for some time in the air-chambers? We do not say that muscular exertion is the cause of increase of urea, *but that remaining in an over condensed atmosphere increases the waste of the system*, and which is confirmed by the increase of urea in their urine, collected at the time the quantity of urea *is admitted to be less.* Moreover, they have that profuse perspiration which always exists on all the men while working in the air-chambers; and does not nitrogen, a part of the waste of the tissues escape through the skin by this profuse perspiration.

It may be said that this profuse perspiration observed, was not perspiration, but the condensation of the respiration, or the condensation of the compressed atmosphere in which the men were working; but this cannot be, because the profuse perspiration covered every part of the body, and even continued for some time after the men had returned into the normal atmosphere.

As for the condensation of the condensed atmosphere, this could not take place, the temperature of the body being nearly 100°, and the surrounding atmosphere

only 48°, consequently lower, its condensation was impossible. This only demonstrates that it was perspiration and very profuse too, which continued, as we have already said, for some time after the men returned into the normal atmosphere, "*but not when returning as quick as possible.*"

Is it then, surprising, that the secretion of the kidneys was sometime interfered with, we mean among the most serious cases reported before we took charge of the men.

This seems to us to be more than sufficient to explain the exhaustion which caused the symptoms observed on the men taken sick who had worked in the air-chambers.

A cause to which we have already alluded in Chapter VII, we think was a too long sojourn in the air-chambers. *From the first day of our professional attendance at the bridge, we suggested that the time of work in the air-chambers was too prolonged*, and might cause a compression continued beyond the vital resistance of some of the liquids of the body, said liquids notwithstanding their slight compressibility, are, according to the laws of physics, nevertheless subject to the same influence of increased atmospheric pressure, as is water in its transformation from a liquid body to a gaseous one; (see our experiments on ebulition of water, Chapter II.) and according to the laws of physiology, we may infer that the circulation of the blood to the periphery of the body having been interfered with, by the influence of increased atmospheric pressure, while in the air-chambers, and a great deal more from the periphery when returning into the normal atmosphere by coming through the air-lock "*as rapidly as possible*," by allowing the too rapid escape of the compressed air from the air-lock, said interference of circulation manifested by the early disintegration of tissues to the superficie of the body — disintegration extending sometimes to deep seated organs, as the kidneys and bladder, as it was found at the post mortem examinations.

But there are also other causes which may predispose, and even produce, on persons going into the air-chambers as laborers, or, as visitors, all the symptoms and effects already observed; and, we think it *necessary*, *nay*, *even important*, to examine those causes. We allude to the necessary time *to remain in the air-lock when goiug into the air-chambers and also when coming out of them.*

The proper time for the men to remain in the air-lock when going into the air-chambers, as also when coming out to return into the normal atmosphere, had been the subject of different opinions, but proximate or specific time to remain in the air-lock, had never been advised, since the commencement of the work, until the time of our observations and regular attendance at the bridge.

In anlaysing each theory or opinion, we looked for a definite or proximate cause or causes of the symptoms observed, as also for an indication of the duration of time to remain in the air-lock when going in and out of the air-chambers; besides, there was no prophylactic means advised for the workmen, nor any treatment followed with satisfactory results, when some of the men were taken sick at the piers, and to avoid, if possible, their removal to the hospital.

We think, by reviewing each theory, we may be able to give our reasons for differing in opinion, and we will also indicate the duration of time necessary to remain in the air-lock, when going in and out of the air-chambers; this duration of time *not being an arbitrary one*, *but based in accordance with the amount of pressure existing in the air-chambers*, and on facts which have come under our observation, and confirm the correctness of our views on the subject.

The first opinion given with which we differ, principally on account of its insufficiency, is as follows:

"*That the affection by which the laborers in the air-*
"*chambers are attacked, is chiefly attributed to the*
"*change from a very condensed to a comparative rare-*
"*fied atmosphere.*"

There is nothing definite in this opinion, even admitting that the change from a condensed atmosphere to the normal one is the cause, but this is not a sufficient explanation. How does it happen? The writer quoted above does not say whether the change was too sudden or too slow; or, if the duration of time to remain in the air-lock was what it ought to have been when the men were coming out of the air-chambers; and if it was not possible to modify or improve the condition in which the men were placed, and to avoid the pathological symptoms observed as a consequence of this change.

The opinion of another writer was that the greatest danger to persons entering the air-chambers is that they enter too rapidly. If only they would admit the pressure more moderately, so that the heart and internal organs could accommodate themselves to this process of congestion.

We agree with this advice, but it is a very incomplete direction to follow. There is no notice taken of the amount of pressure existing in the air-chambers. He says to admit the pressure more moderately, but there is no duration of time even suggested. The amount of pressure has from time to time varied considerably. Supposing that this advice is followed, and that by guessing at the time necessary to remain in the air-lock, the pressure is admitted moderately but without stating the duration of time, there may be a risk of remaining in longer than it is safe; and we ask, What will be the effect on a person remaining too long a time in the air-lock? — For illustration, let us suppose that the pressure is 45 pounds and the temperature is 65° in the air-chambers—according to the explanation we have before given (in Chap. IX.) the temperature

in the air-lock will increase to about 83°—may be more—and may reach even an equal temperature with the one observed and related in chapter VII., which increased to 92°.

Now, let ten men of medium stature—which is generally the number going at one time into the air-lock—remain in the air-lock for a period of over fifteen minutes; we say over fifteen, because less will not be "*moderately*,"—*fifteen minutes being a short time for the pressure existing.* Let them remain over this time, to equalize the pressure with the air-chambers, which is 45 pounds to the square inch, and *take into consideration the capacity of the air-lock, which is six feet in diameter by six feet in height, allowingto each man only sixteen cubic feet to breathe in for over fifteen minutes*; *and at the temperature which has never been less than 74° and as high as 92°, when ten men were in the air-lock and in which small space allotted for those ten men, the carbonic acid evolved by the respiration of each one, amounts to* 191^{84} *cubic inches per minute, which being multiplied by ten amounts to* 1918^{40} *cubic inches, and multiplied by the number of minutes—fifteen—gives a total of* 28,776 *cubic inches of carbonic acid accumulated in this small space during the time of their* remaining in the air-lock, in which a longer time might be attended with danger.

It was the condition in which those men were placed which induced us to observe the variation of temperature in the air-lock conjointly with the existing pressure; and since the commencement of the filling up of the air-chambers with concrete, we noticed its rapid increase, which frequently ranged as high as 80° to 92°, until the completion of the work, on the 27th May, 1871.

It is therefore possible to foresee that the atmospheric condition in which persons going into the air-chambers

may be placed by their remaining too long a time in the air-lock, and that they would certainly run a greater risk of being more affected, and principally the laborers, who had to remain at work in the air-chambers for two hours after entering them, and which sojourn of two hours was in itself sufficient to predispose to the symptoms we have observed and described elsewhere.

We thought it was a capital point, and one not to be overlooked, to ascertain, as near as possible, the time necessary to *remain in the air-lock when going into the air-chambers;* and after repeated observations and experiments, we gave the following directions, according to the pressure and temperature.

We directed that no more than seven persons at a time, laborers or visitors, should enter the air-lock, allowing them twenty-three (23) cubic feet each, instead of sixteen, besides lessening the production of carbonic acid evolved by respiration, and that the duration of time for equalizing the pressure in the air-chambers, *should be one minute for every three pounds of pressure, that is to say, if the pressure was thirty pounds, ten minutes in the air-lock was necessary, and if forty-five pounds, fifteen minutes, and so on, maintaining always the proportion of one minute to every three pounds, which time, when correctly observed, was never attended by the slightest inconvenience among those working in or visiting the air-chambers.*

Now, we have to examine the opinion of the same gentleman as to the sojourn in the air-lock, when coming out of the air-chambers, which direction, on the subject, is very explicit, and is as follows:

"*As to the manner of coming out of the air-lock, I "should think it advisable to come out as rapidly as "possible, for whether they suffer or not, there must take*

"*place a certain degree of reaction to the surface of the* "*body, which is only accomplished by the removal of the* "*atmospheric pressure in entering the open air.*"

With this opinion we differ much, not only as to the time of duration to remain in the air-lock when coming out of the air-chambers, but also as to the effects produced by this spontaneous change, advised "*as rapidly as possible*" from a very condensed atmosphere to the normal one, that we will for illustration take from our observations on the 19th of February last, and when the pressure was only thirty-seven and a half pounds to the square inch.

Let us imagine a workman ready to go to work in the air-chambers; he is in good health, his complexion fair, pulse 80 per minute. This man enters the air-lock and remains in it twelve and a half minutes; his pulse is then 92, but as soon as he enters the air-chambers his pulse, within fifteen minutes, falls to its normal standard, and gradually becomes slower, as his sojourn is prolonged in the condensed atmosphere, so that after two hours work in the air-chambers, we find that same man with a pulse at 69 per minute. This pulse is evidently an *indication of depression of the system.*

Now, this same man, in a depressed condition, leaves the air-chambers, where the temperature is 45°, and, *notwithstanding this low temperature he is covered with profuse perspiration* (*such is the case with all the workmen*) *and in entering the air-lock he is directed* "*to come out as rapidly as possible,*" to return into the open air. Now, it will be observed, that in six and a half minutes —the time directed that this man had to remain in the air-lock to equalize the pressure with the open air—the thermometer *had fallen to 32°, freezing point,* this being caused by the escape of the compressed air from the air-lock in the normal atmosphere.

Now, if the time to remain in the air-lock is shortened, when coming out of the air-chambers, the escape

of the compressed air from the air-lock being still more rapid, the temperature in the air-lock *will decrease still more rapidly*, and be lower than ever before.

Is it advisable, not to say safe, for any workingman, already in an exhausted condition, sufficient to produce all the symptoms heretofore observed, to expose himself to more depressing causes, *as we consider the freezing atmosphere to be, as would be the case by "coming out as rapidly as possible," which, instead of producing a certain degree of reaction to the surface of the body, will prevent all chances of reaction by increasing still more the want of vitality?*

Is it not more rational and safe to make the change from a highly condensed atmosphere to the normal one more gradual, so that if there is to be a reaction to allow it to take place in the open air, which, for persons suffering from the effects of a too long sojourn in a condensed atmosphere, is most favorable to them for recovering from the phenomena which have been so often observed?

One last illustration in confirmation of the correctness of our views.

Has not nearly every man working in the air-chambers, when taken sick, after coming up from their work, complained of epigastric pain, sometimes so violent as to produce syncope? If we look at those men *working in the air-chambers when coming out and entering the air-lock, they are covered with profuse perspiration; five out of six of them, have their chest and epigastrium unprotected for want of sufficient clothing. Is there no danger then that the epigastrium, the liver, the spleen, the diaphragm and the epiploon, which system of blood vessels are comparatively more extended and numerous than in any other part of the body.* Is there no danger that the exposure of those organs to the influence of cold, produced suddenly by the too rapid falling of the temperature to freezing point in the air-lock, "*by coming*

out as rapidly as possible,") will produce that very same congestion that it is so important to avoid?

We leave to every person conversant with the subject, to draw his own conclusion of our expressed opinions.

But it may be asked, how is it possible to explain how it is that some are taken sick from twenty minutes or more after coming up, and their pulse was always slow, from 60 to 68 per minute, and that the pulse of those taken sick immediately after coming up was from 95 to 115 per minute.

To this we will say, that those whose pulse was slow had more endurance to resist exhaustion, and were not yet in the same exhausted condition of those whose pulse was as much as from 95 to 115 per minute, which was the result of complete exhaustion caused by the efforts *made in walking up the circular stairs in the shaft to return to the surface of the piers, when already* in a more complete state of exhaustion on leaving the air-chambers than those whose pulse was slow after coming out.

We also call the attention of our readers to some other supposed causes of the symptoms observed.

From the time the caissons touched the bed of the river, it became necessary to use lights for the men to work with in the air-chambers at the excavating of sand and filling up with concrete. What is known as star candles was used, as also coal oil lamps, but, notwithstanding the condensed atmosphere in which the lights were burning very freely, a large proportion of unburnt carbon escaped into the air-chambers, some of which was inspirated by those exposed to it, and was afterwards expectorated when they returned into the open air.

Some time before we examined this fact, it was supposed by many working in the caissons that this was

injurious to them; but to this we had only to say that it was not so, and that the unburnt carbon escaping from the candles and lamps was, with a proportion of oxygen existing in the condensed atmosphere in the caissons under the influence of pressure, combining and forming carbonic acid, which, as soon as formed, diffused itself through the air-chambers, and was in so small a quantity as to be harmless.

To some this explanation was sufficient, but it gave rise to another theory, which was, *that the amount of carbonic acid thus formed, conjointly with the amount which was evolved by the respiration of each man working in the air-chambers being considerable, that a part remained in the system under the influence of the pressure when in the air-chambers, and acted as poison.*

The theory of the carbonic acid remaining in the system, and to poison it, cannot hold good, for the reason that in the air-chambers—the men perspiring profusely—the carbonic acid found also its exit from the system by the profuse perspiration. It is known in physiology that *it is a standard function of the skin to permit partial arterialisation of the blood, atmospheric oxygen being exchanged for carbonic acid through the skin.*

Now, instead of the atmospheric oxygen only, we have a condensed atmosphere which contains four times as much oxygen, it is then easily seen that the the functions of the lungs not being impaired (*as post mortem examinations have demonstrated*) and perspiration going on freely when the men were working in the air-chambers, if the lungs were unable to remove all the carbonic acid resulting from the waste of the body, the surplus, if there was any, *was eliminated by the skin during the time this perspiration was going on, and which lasted as long as the men remained in the air-chambers, but it was very important not to* check it too suddenly after the men were leaving their work

and when they were entering the air-lock to return into the normal atmosphere, and (*by "coming out as rapidly as possible,"*) but to let that same perspiration continue not only until, but after, the men had returned into the normal atmosphere, and where, after their return, keeping quiet a certain length of time, then the lungs will perform what the skin ceases to do, they will remove the surplus of carbonic acid from the system, if there is any; but this result can be obtained only by remaining in the air-lock the time we have indicated, and which is necessary in the meantime to avoid the appearance of the pathological symptoms already observed. But we do not believe that there was a sufficient quantity of carbonic acid remaining in the system to produce any of the pathological symptoms already observed, and moreover, we will say we observed always that the respiration was normal in every man we examined in the air-chambers, and that each expiration was somewhat deeper than when in the normal atmosphere, and that there was no symptoms of asphyxia observed in any of the cases, which fact was also proved *when the post mortem examinations were held.*

This subject naturally led to the enquiry—What, then, became of the carbonic acid, as there was none found in appreciable quantity when we made our experiments on the 19th February, 1870, nor after, until the completion of the work? To this we will say that the carbonic acid evolved by the respiration of the working men and visitors in the air-chambers, as also from the combination of the unburnt carbon of the candles and lamps with oxygen, or formed from any other causes, that the said carbonic acid thus formed or evolved was diffused through the condensed atmosphere in the air-chambers, and that the condensed air, in which was diffused the carbonic acid, *was constantly escaping under the edge of the caissons through the sand into*

the river, as also by the frequent opening of the doors of the air-lock, which was constantly used for ingress and egress purposes in and from the air-chambers, then allowing to escape its contents of compressed atmosphere at each time, which was replaced by a constant *supply of pure compressed air* by the air pumps working day and night. Hence it was that the quantity of carbonic acid was unappreciable by the ordinary test, in consequence of its small quantity and extreme diffusion; and, consequently, could not have any injurious effect on the men working or remaining in the air-chambers. This applies from the time the caissons touched the bed of the river until they touched the rock, and the filling up of the air-chambers with concrete commenced.

But it may be asked—What became of the carbonic acid in the air-chambers after commencing the filling up with concrete and closing all means of escape for it?

To this we will say, that the carbonic acid, no longer finding its way of escape, instead of accumulating in the air-chambers, as might be supposed, the said carbonic acid which was evolved *was decomposed or absorbed by the constant slackening of the hydraulic lime or hydraulic cement used to make the concrete* for the filling up of the air-chambers.

Before concluding this chapter, we have to say that there exists a comparative difference as to the effect of increased atmospheric pressure on the man as a visitor in the air-chambers and on the man as a laborer, which difference exists in the following facts:

1. The visitor going into the air-chambers is to remain only a short time, and when he goes through the air-lock he is always accompanied by a competent person or an officer of the bridge, and every precaution is taken while remaining in the air-lock, where few enter at a time, and, according to the pressure, remain in the air-lock the duration of time we have indicated as a safe one.

2. The stay in the air-chambers rarely exceeds half an hour, very few having remained an hour, and their visit only occasional, and in some instances, only a solitary one.

3. Any casual visitor, before his or her visit to the air-chambers, which may be looked on as a pleasure trip, is always supposed to be in good health; and no strangers to the work, visiting the piers, are permitted to go into the air-chambers without being warned of the effects of the compressed air, which might, possibly, be disagreeable to them without being injurious. *This warning was sufficient to prevent many from visiting the air-chambers if they were not in the condition of health to do it, notwithstanding that they came for that special purpose.* If ever it happened that among the visitors there were some of irregular habits, their sojourn of an hour in the air-chambers, without repeating their visits, and in the meantime taking all the precautions necessary in going in and coming out, insured them against any further contingency resulting from their visit.

4. As to the frequent visits made by the officers of the bridge into the air-chambers, it is superfluous even to say, that all of them knowing the effects and consequences to which they were exposed, never tried to go into the air-chambers unless they were in good health, and as men of regular habits they never exposed themselves in any condition which could, in the slightest degree, predispose them to be affected by the increased atmospheric pressure existing in the air-lock or in the air-chambers.

CHAPTER XI.

OPINIONS BASED ON FACTS AND OBSERVATIONS.

As we have already said in Chapter V, we have very little to add to the pathological symptoms described and pathological changes observed during the *post mortem* examinations made by other professional gentlemen. We agree with their correctness; but as to their causes, and the conditions in which those changes took place, we differ, and will say that we do believe that those pathological changes were not caused by the *immediate* effect of exposure to a condensed atmosphere, but the result of a reaction produced too suddenly on those taken sick, by the means used to bring on the reaction; among which, we may name such as the *administering of alcoholic stimulants in too large doses for the nature of the cases, the hot bath administered immediately after being taken sick*, and which was followed in some cases by immediate paresis, and even paralysis, from which the patients recovered very slowly, if at all—a fact which induced us to *forbid the use of the bath entirely in the treatment of such cases.* We may also mention, as a means of bringing on reaction, the *injudicious use of magneto-electricity, and the removal of the patients from the piers too soon after they were taken sick*, and when they were not in a condition to support such removal.

But, it may be asked, how is it possible that those pathological changes were observed during the *post mortem* examinations, and how to explain or account *for the changes observed on the brain, its membrane,*

and the spinal cord, and not admit that the increased atmospheric pressure is the immediate cause of these changes?

We will then say, that those pathological changes, if we examine the time when each patient was taken sick, and how long it was before he died, and what was then the pathological changes observed during the *post mortem* examinations, it is easily demonstrated that the pathological changes existing after death, as also the pathological symptoms observed during life, *were not caused by the compressed air, of which they would probably have recovered, as did the forty-five others we reported*, but that those pathological changes were brought on as a sequel of the reaction, interfered with *by increasing that same reaction to a degree which was too sudden to be safe, and lessening the chances of the recovery of those attacked.*

We think this is applicable to the three cases which form the subject of the first, second and fifth *post mortem* examinations in Chapter V, where the reaction was followed by inflammation of the brain, its membranes, and also of the spinal cord, *which cases having run their regular course of time and terminating in death, presented the same pathological changes that in cerebro spinal meningetis, which, with a few exceptions, terminate fatally, from the fifth to the fifteenth day, and in which cases the post mortem examination reveal the same pathological changes as those of which we have spoken.*

As for the third and fourth *post mortem* examinations, for which we refer our readers to Chapter V; they are a confirmation of the correctness of our views enunciated in Chapter X, on the influence of too sudden transition from a temperate atmosphere to a freezing one, as also, from the too sudden removal from the highly increased atmospheric pressure into the normal one, (by coming *out of the air-lock "as rapidly as possible,"*) at which

time the *circulation* of the superficial parts of the body is interfered with, seems to us the cause of the temporary increased arterial pressure of the blood on the brain and spinal cord, and, if to this pressure existing on the brain and spinal cord of any person after coming out of the air-chambers, and that after reaching the open air that person *is taken sick; if then, you still increase by bringing on a too sudden reaction by the use of too much stimulant, hot bath, electricity or even removal from the piers*, it may result in a great number of fatal cases, and the same pathological changes will be observed as in those two cases to which we have referred.

Moreover, we will state, that out of forty-nine cases we had under our care, forty-five of them, who were kept at the piers for immediate treatment, when they were taken sick, not only recovered, but were able to go home by themselves within twelve hours, and to resume work in a few days. *Three of the cases had a hot bath administered to them*, and when taken out were paralysed; the fourth one, which is case XXXV, chapter V, *died of sheer exhaustion, as it was proved by the post mortem examination that he had taken no food during the whole day, but had been drinking.*

We think we have sufficiently explained the causes of the pathological symptoms observed during life and pathological changes after death, and we have now only to say that, as to the cause of immediate paresis or paralysis happening on the men shortly after coming up from working in the air-chambers, and after returning into the open air, *they are not the result of inflammation of the brain or of the spinal cord, which could not yet have taken place*, but exist only as the result of a too sudden or too strong reaction, succeeding to a general depression of the system, *which is occasioned by too long a sojourn in a condensed atmosphere*, and then paresis or paralysis is but the result of reflex

action, *caused by the spontaneous refrigeration* of the whole system, but principally *of all the abdominal organs.*

After all the facts and observations we have brought under the consideration of our readers, we have come to the conclusion that it is possible to use compressed air with comparatively few risks of danger to those working in the air-chambers, and with safety to life, even if the working men have to be exposed *to a pressure of 55 pounds to the square inch*, and exclusive of the 15 pounds of our ambient atmosphere, provided that the following directions be strictly complied with.

First.—A rigid and close examination as to the fitness of the men who are to be employed in the air-chambers—an examination which will lessen the risk for persons unfit to expose themselves to be affected by the exhaustive power of the compressed air, and which may cause on their system pathological symptoms of which men in fit condition will be exempt.

Second.—Men of middle and low stature and well built should be preferred; observation has demonstrated that they resist exhaustion better.

Third.—Single men of good habits should be selected in preference to any others.

Fourth.—No man should use tobacco, either smoking or chewing, while working in the air-chambers.

Fifth.—Only men of temperate habits and regular diet, consisting of three substantial meals a day, of which animal food shall form the principal part; and if using wine, beer, or liquor, to do it very sparingly.

Sixth.—No person having heart disease or aneurism of large blood vessels, nor any one having any chronic sore throat, which may have closed the eustachian canals; no person having an advanced lung disease; and no lung diseases at all after the pressure shall be over 25 pounds to the square inch.

Seventh.—All the men working in the air-chambers should, as far as possible, wear their beard and whiskers to act as a natural protector against the sudden change of temperature when coming out of the air-chambers and remaining in the air-lock.

Eighth.—Every person working in the air-chambers ought to wear a flannel undershirt, and a flannel belt wrapped at least twice around the abdomen, and their feet should be kept perfectly dry and warm by the use of *woolen stockings and long water-proof boots.*

Ninth.—Any one going into the air-chambers as a laborer ought to leave off all his superfluous clothing a few minutes after entering the air-chambers or caissons, and before commencing work. But when leaving the air-chambers to return into the normal atmosphere, and before entering the air-lock, it is an imperative necessity not only to put on again his clothing, but, if possible, to add more, such as an overcoat or blanket, which could be dispensed with immediately after coming out of the air-lock into the shaft or open atmosphere.

Tenth.—Every workman after coming out of the air-chambers should immediately lie down and rest for at least one hour in a sheltered but well ventilated place, where the temperature should not be lower than 65°, and not above 75°, Farenheit.

Eleventh.—The most important of all, and to which we have already alluded, but to which we again call particular attention, is the duration of time to remain in the air-lock when going into the caisson or air-chambers, which should always be at the rate of ONE MINUTE FOR EVERY THREE POUNDS OF PRESSURE *to the square inch, to equalize the pressure in the air-lock with the air-chambers.* And when coming out to return into the normal atmosphere, the duration of time in the air-lock to *let the compressed air escape and to equalize the*

pressure with the normal atmosphere should be at the rate OF ONE MINUTE FOR EVERY SIX POUNDS OF PRESSURE *to the square inch.*

Besides the above directions, we believe, from our repeated observations and experiments, that the time the men ought to work in the air-chambers should not exceed, per day, the time indicated below, and which is in accordance with the amount of pressure to which the men may be exposed; and, in our opinion, is necessary to avoid, as far as possible, all manifestations of pathological symptoms.

DURATION OF THE TIME OF WORK PER DAY FOR THE LABORERS IN THE AIR-CHAMBERS OR CAISSONS.

The pressure being from 15 to 20 pounds to the square inch, two hours' work three times a day, with two hours' rest between each two hours' work.

From 20 to 25 pounds to the square inch, two hours' work three times a day, with three hours' rest between each two hours' work.

From 25 to 30 pounds to the square inch, two hours' work twice a day, with three hours' rest between each two hours' work, and one hour's rest at the piers after the last two hours' work.

From 30 to 35 pounds to the square inch, two hours' work twice a day, with four hours' rest between each two hours, and one hour's rest at the piers after the last two hours' work.

From 35 to 40 pounds to the square inch, one hour's work three times a day, with two hours' rest between each hour of work, and one hour's rest at the piers after the last hour's work.

From 40 to 45 pounds to the square inch, one hour's work twice a day, with four hours' rest between each time of work, and one hour's rest at the pier after the last hour's work.

From 45 to 50 pounds to the square inch, one hour's work twice a day, with six hours' rest between each time of work, and one hour's rest at the piers after the last hour's work.

From 50 to 55 pounds to the square inch, one hour's work once a day, and two hours' rest at the piers after the work.

The rest directed at the piers, after the men had done work for the day, was to oblige them to rest until they should have partially recovered from the exhaustion caused by working in the air-chambers, which, notwithstanding its short duration, if they were not compelled to rest after coming out—principally after the pressure was over 30 pounds to the square inch—would gradually, after a few days repeated work, impair their strength to resist the effect of the increased waste going on on their system while working in the air-chambers, and which has been mentioned before.

CHAPTER XII.

SINKING OF THE CAISSON FOR THE EAST ABUTMENT PIER —RESULTS AFFIRMATIVE OF THE SAFETY OF USING COMPRESSED AIR FOR SINKING PIERS IN THE CONSTRUCTION OF BRIDGES IN DEEP WATER, AND FOR GENERAL MARITIME PURPOSES.

A copy of the first eleven chapters of this small work were submitted to Mr. J. B. EADS, chief engineer of the Illinois and Saint Louis Bridge, in the month of September, 1870. After the perusal of its contents, desiring to avoid by all possible means the same pathological symptoms observed on the men who had been working in the air-chambers of the east and west caissons, he felt the necessity of having proper attendance given, and prophylactic means employed, for the men working in the air-chambers when the east abutment caisson should be sunk to a certain depth, and, if possible, to avoid the recurrence of accidents during the sinking of this caisson to the rock, and the filling up of the air-chambers until finished.

The work of sinking the caisson had commenced on the 15th of November, 1870, and progressed until the 31st January, 1871, when we were requested to commence our visits at the bridge.

On the 1st February, 1871, we commenced our professional visits. The work was progressing in the following manner:

Some very important improvements had been made in the construction of the caisson, and which had for their object not only the comfort, but also the safety, of those working in it during its sinking.

The main or central shaft, ten feet in diameter was carried down into the air-chambers near the bottom, and there were at the bottom of the shaft two air-locks *eight feet in diameter by seven feet six inches in height* (*whereas in the east pier caisson there was only one*), *and each air-lock of double capacity for the same number of men* who had to go through them to work in the air-chambers.

"The central shaft was used only for the workmen, and was provided with a circular stairway; but to avoid the rather hard labor of walking up, and using more muscular exertions after leaving the air-chambers, in addition to the stairways, an elevator or lift to bring the men up was constructed." *This not only contributed to lighten their labor, but avoided the difficulty of breathing to many of them, as we experienced in our subsequent visits at the east pier, in ascending one hundred and seventy* (*170*) *steps, and which would be one hundred and ninety* (*190*) *in this caisson.* It prevented also further exhaustion of the men after their repeated exposure in a very condensed atmosphere.

"The method of lighting the air-chambers was also improved, by burning the candles under an inverted glass funnel or chimney communicating outside the air-chambers by pipes, through which the escape of compressed air was regulated by a valve, thus producing above the burning candle a draught which carried the smoke off."

This improvement in lighting, certainly added to the comfort and cleanliness of the workmen in the air-chambers, who had a better appearance after coming up to the surface of the pier.

From the first day of our taking charge of the men working in the air-chambers, we visited them three times daily; the caisson was then fifty-six (56) feet under the surface of the river, and the pressure in the air-chambers twenty-seven (27) pounds to the square inch.

There were seventy-six (76) men working in the air-chambers, divided into four gangs, and working two (2) hours three times a day, with two hour's rest between each time of work. *All of them had worked before in the East and West pier air-chambers.*

During the month of February the number of men was increased to one hundred and forty (140). The seventy-six men already at work, *after examination, were found to be able to continue at work in the air-chambers;* but as the pressure increased every day, it became necessary that each new applicant for work in the air-chambers be *examined carefully as to his fitness for such work.* Besides the seventy-six men already working, one hundred and thirty-three (133) more men were examined—of whom sixty-four (64) were found fit for such work, and *sixty-seven (67) were rejected for the following causes:*

25 for general debility, caused by intemperance.
6 for consumption.
3 for epilepsy.
8 for over 45 years' old.
5 for large ulcers of legs.
2 for disease of the heart.
11 having had chills within two weeks.
7 for general debility, caused by exposure or sickness.

The number of men working was 140, which were duly enrolled, as follows:

11 were from 18 to 20 years' old.
70 " " 20 to 25 " "
38 " " 25 to 35 " "
21 " " 35 to 45 " "

Their nationality was as follows:

39 natives of United States.
12 " England.
56 " Ireland.
26 " Germany.
7 " Canada.

Their stature, with few exceptions, was below medium; 27 of them were married.

As a generality they were intelligent, and seemed disposed to follow the physician's directions for their comfort, health and safety.

A building of convenient size was erected with berths in it for the men *to rest between their time of work.* Another building was also provided for a hospital, containing sixteen (16) beds, in case it should become necessary.

Each man working in the air-chambers was required to take his dinner at the pier, and three quarts of a pint of strong beef tea was provided for each man with his dinner. No one was allowed to leave the pier from the commencement of their work in the air-chambers until one hour after their work was over for the day.

We called the muster-roll every day, and each *man was examined by us;* if any were found unfit, from any cause, to work in the air-chambers, he was prevented from doing so, and was re-examined twice a day until we found him fit to return to work.

On the seventh day of February, the pressure in the air-chambers being thirty-two (32) pounds to the square inch, the time of work was reduced to two hours twice a day, with four (4) hours' rest between each time of work, and one (1) hour's rest at the pier after the last two hours' work.

On the ninth, the pressure having increased to thirty-four and a half (34½) pounds, the time of *work was again reduced to one* (1) *hour three* (3) *times a day, with three* (3) *hour's rest between each time of work.* The pressure continued to increase every day, and on the first of March, there being forty-five (45) pounds pressure to the square inch, the time of *work was still further reduced to forty-five* (45) *minutes, twice a day, with six hour's rest between each time of work,* and one hour's rest at the pier after the last forty-five minute's

work. The same duration of work was continued until the completion and filling up of the air-chambers, and during *which time the pressure was as high as fifty* (50) *pounds to the square inch.*

From the first day of our attendance at the pier, the time necessary for the men to remain in the air-locks, to equalize the pressure, when going into the air-chambers to work, and when coming of them, *was strictly observed according to our directions, based on the pressure existing in the air-chambers at the time: Three pounds of pressure to the square inch per minute was let into the air-locks until the pressure was equalized with the air-chambers*, when going from the normal atmosphere into the air-chambers, *and six pounds of pressure to the square inch per minute was removed when in the air-locks*, and coming out of the air-chambers to return into the normal atmosphere.

The regularity of the time necessary to remain in the air-locks, when going into and coming out of the air-chambers, was obtained by means *of an indicator, graduated and set by us every day acccording to the pressure existing in the air-chambers.*

The regularity of the duration of time which the workmen *remained in the air-locks or intermediate chambers to equalize the pressure, when going into or coming out of the air-chambers*, certainly prevented the increase of temperature during their stay in the air-locks when going into the air-chambers, the temperature never increasing above eighty-three (83) degrees, *instead of ninety-two* (92), *as in the air-lock at the East pier*, and the average was seventy-two (72) instead of eighty (80) degrees; when coming out from the air-chambers to return into the normal atmosphere it prevented a too great decrease of temperature, which was never below fifty-six (56) degrees, instead of *thirty-two* (32), *freezing point, as it had been observed many times in the air-lock at the East pier.*

The minimum temperature observed in the air-chambers was fifty-two (52) degrees, and the maximum sixty-seven (67), but the daily average was sixty (60) degrees during the progress of the work.

It will be seen that those changes in the condition of the atmosphere *in the air-locks and air-chambers, and the daily examination of the men working in them*—if some of the men were affected by the condensed atmosphere, all but one recovered, and none of those who recovered were disabled.

One death occurred, but it can be considered as an exception—*and affirmation of the necessity of following the directions given by us for insuring* safety.

The following twenty-eight (28) observations of cases are those which happened during the sinking of the East abutment caisson.

CASE L.—8TH FEBRUARY, 1871.

Barometer 29° 50′. Thermometer 40°. Weather cloudy. Pressure 33½ pounds.

JAMES HOWARD, 34 years; Ireland; taken sick after the second watch he worked, and about twenty minutes after coming up; patient of medium stature, well-built.

SYMPTOMS.

Face livid; pulse 60 per minute; complains of epigastric pain, and paresis exists in both legs, which, half an hour afterward, became a plain case of paraplegia.

The treatment followed was similar to other cases in Chapter VII, and twelve hours after he was able to go home without assistance.

CASE LI.—9TH FEBRUARY, 1871.

Barometer 27° 70′. Thermometer 21°. Weather clear. Pressure 34½ pounds.

PATRICK KILLEEN, 19 years; Ireland; had worked two weeks; taken sick about twenty-five minutes after

coming up. This case was similar to case I. *The same treatment* was followed, and, twelve hours after he was taken sick, he was able to go home.

CASE LII.—11TH FEBRUARY, 1871.

Barometer 29° 60′. Thermometer 24. Weather snowing. Pressure 35½ pounds.

YONAN LULL, 28 years; Germany. This man had been taken with diarrhœa the day before, but felt well when he went to work; was taken sick immediately after coming up.

SYMPTOMS.

Face livid; pulse 105 per minute and feeble; suffered from paresis of both legs.

The *same treatment* was followed, and in twelve hours he was able to go home with some assistance.

CASE LIII.—12TH FEBRUARY, 1871.

Barometer 29° 48.' Thermometer 24°. Weather cloudy. Pressure 36½ lbs.

JAMES WILSON, 21 years; Ireland; had worked two months; was taken sick after the second watch, and twenty-five minutes after coming up; of medium stature. This case was similar to case I. The *same treatment* was followed, and twelve hours after he went home.

This case, as also cases LI and LII, were brought on by the men themselves, who, instead of resting immediately after coming up, as we directed, had been running around, and were consequently taken sick.

On the 20th February, the pressure being forty (40) pounds to the square inch in the air-chambers, a leak sprung in the main or central shaft, where *the elevator was, and prevented its use to bring up the men after leaving the air-chambers.* During the time *the elevator could not be used*, and the men had to walk up one

hundred and seventy (170) steps, turning on a radius of five feet, the following cases occurred, which still demonstrate the truth of the theory of exhaustion.

CASE LIV.—20TH FEBRUARY, 1871.

Barometer 29° 40′. Thermometer 44°. Weather clear. Pressure 40 lbs.

JAMES CASEY, 28 years; United States; had worked twelve days; was taken sick half an hour after coming up. His case was similar to case I, but only more serious. The *same treatment* was followed, and twelve hours after he was convalescent.

CASE LV.—20TH FEBRUARY, 1871. PRESSURE, 40 LBS.

H. DONNELLY, 24 years; Ireland; had worked two weeks; was taken sick twenty minutes after coming up; case similar to case I; *treatment* same, and twelve hours after was able to go home.

CASE LVI.—20TH FEBRUARY, 1871. PRESSURE 40 LBS.

JOHN KHEO, 20 years; United States; had worked ten days; was taken sick twenty minutes after coming up; case similar to case I; *same treatment* followed, and twelve hours after went home well.

CASE LVII.—21ST FEBRUARY, 1871. PRESSURE 40 LBS.

EDWARD GALLAGHER, 28 years; Ireland; had worked two weeks; taken sick about half an hour after coming up; similar case to the preceding one; *same treatment*, and twelve hours after was he able to go home well.

On the 21st February the elevator was again in running order. No more cases happened until the 24th, when the pressure having increased to forty-two and a half (42½) pounds—*the time of work being then too long for the pressure existing in the air-chambers*—six (6) cases happened in the course of the day, but this was also caused by the fault of the men who were taken sick, in consequence of not resting and keeping quiet as soon as coming up from the air-chambers.

CASE LVIII.—25TH FEBRUARY, 1871. PRESSURE 42½ LBS.

FRANK JOURDAN, 23 years; United States; had worked three months; was taken sick twenty minutes after coming up, after the third watch of one hour. His case was similar to case I. *Same treatment*, and twelve hours after he was able to go home.

As we have said in chapter VII, the *barometrical and thermometrical changes having no marked influence on the production of cases*, we think it unnecessary to continue to record them.

CASE LIX.—25TH FEBRUARY, 1871. PRESSURE 42½ LBS.

WILLIAM O'BRIEN, 37 years; Ireland; had worked nine days; was taken sick fifteen minutes after coming up, after the third watch of one hour; same as case I; *same treatment*, and twelve hours after was able to go home.

CASE LX.—25TH FEBRUARY, 1871. PRESSURE 42½ LBS.

F. BUEL, 20 years; United States; had worked three months; was taken sick twenty minutes after coming up, and after the third watch of one hour; case similar to case I; *same treatment*, and went home well.

CASE LXI.—25TH FEBRUARY, 1871. PRESSURE 42½ LBS.

L. BUEL, 23 years; United States; had worked two months; taken sick, twenty minutes after coming up, after the third watch of one hour; case same as the preceding; *same treatment*, and twelve hours after was able to go home.

CASE LXII.—25TH FEBRUARY, 1871. PRESSURE 42½ LBS.

JERRY WHEELER, 25 years; Ireland; had worked three weeks; was taken sick twenty minutes after coming up, after the third watch of one hour; case similar to the preceding; *same treatment* followed, and twelve hours after had completely recovered.

CASE LXIII.—25TH FEBRUARY, 1871. PRESSURE 42½ LBS.

PATRICK HEALEY, 20 years; Ireland; had worked three months; was taken sick fifteen minutes after coming up, after the third watch of one hour; case similar to case I; *same treatment*, and twelve hours after had completely recovered.

From and after the 26th February, *the duration of time of work in the air-chambers was reduced to forty-five minutes twice a day, with six hours' rest between each time of work, and one hour's rest at the pier after the last time of work.* No other case happened until the 18th March, when, at that time—*the elevator being out of running order—two cases happened as follows:*

CASE LXIV.—18TH MARCH, 1871 PRESSURE 46 LBS.

H. DOWNIE, 24 years; United States; had worked three months; was taken sick a few minutes after coming up. This case was similar to case VII—even more serious. The *same treatment* was followed, and twelve hours after, he had completely recovered.

CASE LXV.—18TH MARCH, 1871. PRESSURE 46 LBS.

E. WAGNER, 28 years; Germany; had worked three months; was taken sick immediately after coming up. This case was the same as case XXVII, but more serious. The *same treatment* was followed, but the patient remained twenty-four hours in the hospital at the pier, before he was able to go home, and after a few days rest, he had entirely recovered.

The safety with which the men had been working in the air-chambers, and the immediate recovery of those taken sick, had made the men reckless of danger, and the twelve following cases were mainly caused by the non-observance of the directions given to them, not to walk up the stairs, but to be brought up by the elevator used for that purpose; secondly, to lie down and rest immediately after coming up, and thirdly, not to drink

any water for at least half an hour after leaving the air-chambers—*directions which were not complied with by those taken sick.*

Moreover, as a proof of the necessity of complying with our directions in order to insure safety, we might say that, notwithstanding we had been paralyzed before, as related in Chapter III, we went into the air-chambers of the east abutment caisson during its sinking to the rock, and we never experienced any inconvenience from our often repeated visits.

CASE LXVI.—21st March, 1871. Pressure 46 Lbs.

John Lambert, 26 years; Germany; had worked three months; was taken sick twenty minutes after coming up from the second watch. Case similar to case I; *same treatment;* recovered, and twelve hours after was able to go home.

CASE LXVII.—23d March, 1871. Pressure 46 Lbs.

Gay Buel, 19 years; Ireland; had worked three months; was taken sick half an hour after coming up from the second watch. Case similar to preceding one; *same treatment*, and recovery.

CASE LXVIII.—24th March, 1871. Pressure 48 Lbs.

John Murray, 23 years; Ireland; (gas-fitter;) had worked only four days; was taken sick twenty minutes after coming up from the first watch, *having remained at work two hours in the air-chambers*, instead of forty-five minutes, and by not lying down and resting immediately after coming up. His case was similar to the preceding; *the treatment* the same, and twelve hours after, had entirely recovered.

CASE LXIX.—26th March, 1871. Pressure 48 Lbs.

Henry Goodaple, 28 years; United States; had worked three and a half months; was taken sick twenty

minutes after coming up from the second watch. Case similar to case I; *same treatment*, and in twelve hours went home well.

CASE LXX.—3D APRIL, 1871. PRESSURE 48 LBS.

SIMON PIERRE, 45 years; Germany; had worked two months; was taken sick fifteen minutes from the time of coming up after the second watch. Case similar to case I; *same treatment* followed, and recovery.

CASE LXXI.—4TH APRIL, 1871. PRESSURE 47 LBS.

MIKE GLEASON, 23 years; Ireland; had worked three months and a half; was taken sick about half an hour after coming up from the second watch. This case was similar to the preceding; *same treatment* followed, and twelve hours after he had entirely recovered.

CASE LXXII.—9TH APRIL, 1871. PRESSURE 47 LBS.

JOSEPH SMITH, 42 years; Ireland; had worked three months and a half; was taken sick twenty minutes from the time of coming up after the second watch. Case similar to case I; *same treatment*, and in twelve hours had entirely recovered.

CASE LXXIII.—9TH APRIL, 1871. PRESSURE 47 LBS.

WILLIAM JONES; 32 years; England; had worked two months; was taken sick about the same time as case LXXII. Case similar to it; *same treatment*, and recovery.

CASE LXXIV.—12TH APRIL, 1871. PRESSURE 47 LBS.

JAMES WALSH, 22 years; Ireland; had worked three months and a half; was taken sick immediately after coming up. This case was similar to case I, but more serious; *same treatment* followed, and after twelve hours had entirely recovered.

CASE LXXV—14TH APRIL, 1871. PRESSURE 49 LBS.

J. A. HOOTS, 25 years; Germany; had worked three months and a half. This case is an illustration of the consequences of the non-observance of the directions given by us to the men working in the air-chambers, and of the fatal result.

This man had, for a few days, been drinking beer rather too freely, principally after his day's work was over; the day he was taken sick *he had not brought his dinner with him, and instead of resting at the pier, after coming up from the air chambers*, he went home, about a quarter of a mile distant, on the Illinois shore, and, instead of taking the proper time to eat his dinner, he swallowed his food without mastication, and returning to the bridge, drank some beer, and then went to work again in the air-chambers, and after coming up, instead of resting and keeping quiet at the pier, as every man was required to do, he went home immediately, where, on arriving, he was taken sick, and commenced to vomit the contents of the stomach, in which was found pieces of meat the size of a walnut. Within a few minutes after, general paralysis supervened, and he was in so critical a condition as to be unable to be removed from his boarding house to St. Luke's Hospital for three days. This patient showed similar symptoms and his case the same course as XVII, chapter VII, and he died on the 28th day of April.

CASE LXXVI.—21ST APRIL, 1871. PRESSURE 49 LBS.

——— HAWKINS (foreman), 42 years; United States; had worked four months, and was taken sick immediately after coming up, after the last watch, having walked up the circular stairs, instead of being brought up by the elevator. This case was similar to case VI. The *same treatment* was followed, and twelve hours after he was able to go home, but felt weak. After a few days' rest, he was able to resume work.

CASE LXXVII.—26TH APRIL, 1871. PRESSURE 47 LBS.

JOHN SULLIVAN, 35 years; Ireland; had worked four months; was taken sick half an hour after coming up, and on reaching home, not far distant, for which he started from the pier without resting, as directed to do. I saw him an hour after he was taken sick. The case was similar to case VI. The *same treatment* was followed, and twenty-four hours after he had entirely recovered.

Now, if we take a retrospective view of the twenty-eight (28) cases which had occurred during the sinking and filling up of the east abutment caisson, it will be seen that twenty-seven (27) *of them recovered completely, and many returned to the same work*, and that the only death which occurred was caused by the fault of the deceased, *in not following the directions given by us to every man working in the air-chambers.*

We think we may claim to have demonstrated the correctness of the theory of exhaustion, which is corroborated by the examination of the urine of forty-two (42) more men working in the air-chambers, to ascertain the quantity of urea existing in it, when the pressure in the air-chambers had not been less than forty-five (45) pounds to the square inch for over three weeks.—This examination was made on the 28th, 29th, and 30th March, 1871, when the men were in the same condition as were the thirty-two (32) men referred to in chapter VII. The following are the results of this examination:

No.	NAMES.	Age.	Had worked in the Air-chambers.	Spec. Gra'y.	Chemical Reaction.	Remarks.
37	Dennis Deering	24	3 months.	1025	Acid.	
38	Henry Malin	30	2 "	1025	"	
39	William Rowlett	28	2 "	1025	"	
40	Joseph Moran	25	3 "	1025	"	
41	John Schwan	21	3 "	1025	"	
42	E. Lemons	19	3 "	1025	"	
43	G. Clark	29	3 "	1026	"	
44	James Tafee	26	3 "	1026	"	
45	John McDonald	27	3 "	1024	"	
46	Richard Millett	32	3 "	1024	"	
47	Richard Colgan	38	3 "	1024	"	
48	Gam. B. Clancey	26	3 "	1025	"	
49	Patrick Killeen	19	2 "	1029	"	Case 51.
50	Timothy O'Keefe	35	2 "	1025	"	
51	Joseph Smith	33	3 "	1025	"	
52	John Sullivan	35	2 "	1028	"	Case 78.
53	Will Whistlick	28	3 "	1027	"	
54	John Sanders	24	2 "	1028	"	
55	James Walsh	22	3 "	1030	"	Case 74.
56	Dennis Dayle	21	2 "	1025	"	
57	J. L. Winkell	31	2 "	1027	"	
58	M. Dumphy	38	3 "	1025	"	
59	James Watkins	25	2 "	1025	"	
60	J. Wheelan	24	2 "	1025	"	
61	Simons Pierre	34	2 "	1028	"	Case 70.
62	Lewis Buel	23	3 "	1029	"	Case 61.
62	G. Buel	19	3 "	1030	Neutral.	Case 60.
63	Henry Harvey	19	3 "	1025	Acid.	
64	Henry Goodaple	28	3 "	1029	"	Case 69.
66	C. A. Thompson	28	3 "	1025	"	
67	R. Decourcy	28	3 "	1028	"	
68	John Kheo	20	2 "	1028	"	Case 57.
69	Edward Wagner	28	2 "	1030	"	Case 65.
70	John Wall	24	2 "	1025	"	
71	Lewis Gibber	28	3 "	1026	"	
72	Fred. Meyer	30	3 "	1030	Neutral.	
73	John Walton	26	2 "	1029	"	
74	John Murphy	18	2 "	1026	Acid.	
75	Patrick McCarty	45	3 "	1028	"	
76	John Sanderson	28	2 "	1028	"	
77	John A. Hoots	25	3 "	1029	"	Case 65.
78	——— Winkelmeyer	30	2 "	1026	"	

There was no albumen in the urine examined, the test of heat and nitric acid having been used for each one.

Besides the tabular statement above, the urine of every man taken sick was examined, and the minimum of specific gravity was found *to be never less than 1028*, but in the majority of cases it *ranged from 1030 to 1036*. The urine was, in all cases, obtained after the second micturition, and about twelve hours after they were taken sick. *The quantity of urine voided was also always greater* than when in good health.

Notwithstanding the profuse perspiration of each man working in the air-chambers, the *quantity of urine secreted by each man in good health, far from being less, was above the average, and taking, at random, five men working in the air-chambers, say, numbers* 70, 71, 72, 73, and 74 *of the above table, each man averaged from twenty-eight* (*28*) *to thirty* (*30*) *ounces of urine, which were taken separately between seven o'clock*, A.M., *when they commenced work, and seven o'clock*, P.M., *the time they were leaving the bridge, making only half of the quantity of urine secreted for twenty-four hours;* and if, taking into consideration the quantity of urea found after each examination in the urine, taken at a time *when the urea is always to be found in minimum quantity*; it must be then admitted that the quantity of urea produced in twenty-four hours far exceeded the normal quality found in the urine of a healthy laboring man, when working in the normal atmosphere.

Arriving at the end of our work, we must recapitulate the facts we have advanced.

First. There exists no specific prophylactic against the effects of compressed air on man.

Second. The effects of compressed air on man, under a pressure of twenty (20) pounds to the square inch or less, *increases the energy of the physiological functions of the whole system*, without producing pathological symptoms and effects. [*This is understood only to persons in good health.*]

Third. After the pressure of the condensed atmosphere has reached twenty (20) pounds, and is still increasing, *it is only by the strictest compliance with certain rules, and taking such precautions as those indicated in Chapter XI*, that it is posible to use compressed air as ambient atmosphere where men can work and avoid the pathological symptoms and effects, which are the subjects of this work.

Fourth. Compressed air can be used with *comparative safety, even at the pressure of fifty-five (55) pounds to the square inch*, for submarine purposes without any serious result to those working in the compressed ambiant atmosphere, and we insist that, notwithstanding *the prejudice* NOW EXISTING AGAINST ITS USE—this prejudice must yield before its highly useful agency to engineering, as a means of sinking piers for the construction of bridges in deep water, as well as for foundations of light houses, or other works for maritime purposes.

Notwithstanding, the many imperfections which, doubtless, this unpretentious work contains, we must claim as having been actuated in its production by but one motive, namely—the demonstration of the truth of facts which we had observed, and we think may be of some interest to the medical profession by the results we obtained.—Results, important, as well as useful, for engineering purposes. We expect that a perusal of this small work by our professional brethren at large, will, if not meeting their approval, at least open the field for further investigations, which, we hope, will be followed by the same results that we obtained while attending the men who had been suffering from the effects of increased atmospheric pressure after coming up from working in the air-chambers in the caissons of the piers of the Illinois and St. Louis Bridge, at St. Louis, State of Missouri, United States of America.

ERRATA.

Page 8, line 23, of which were, *read* of which where.
Page 11, line 10, bladder sand rectum *read* bladder and rectum.
Page 12, line 36, phenomenas *read* phenomena.
Page 13, line 5, *read* uninteresting.
Page 14, line 1, phylosophical, *read* philosophical.
Page 14, line 7, be effected, *read* be affected.
Page 14, line 26, sood health *read* good health.
Page 15, line 20, our breathing *read* our respiration.
Page 16, line 16, our breathing, *read* our respiration.
Page 21, line 10, resectively, *read* respectively.
Page 32, line 16, parepsis *read* parapsis.
Page 46, line 28, parepsis *read* paresis.
Page 51, line 34, he discharged, *read* was discharged.
Page 52, line 10, parepsis, *read* parapsis.
Page 54, line 30, each *read* of each.
Page 101, line 16, anlayzing *read* analyzing.
Page 112, line 30, its membrane *read* its membranes.
Page 115, line 34, eustachian canals *read* eustachian tubes.
Page 123, line 20, *read* of indicators attached to the equalizing valves, said indicators,
Page 134, line 17, quality *read* quantity.
Page 134, line 33, is posible *read* is possible.

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